

ANNUAL REPORT
of the
WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1954-55



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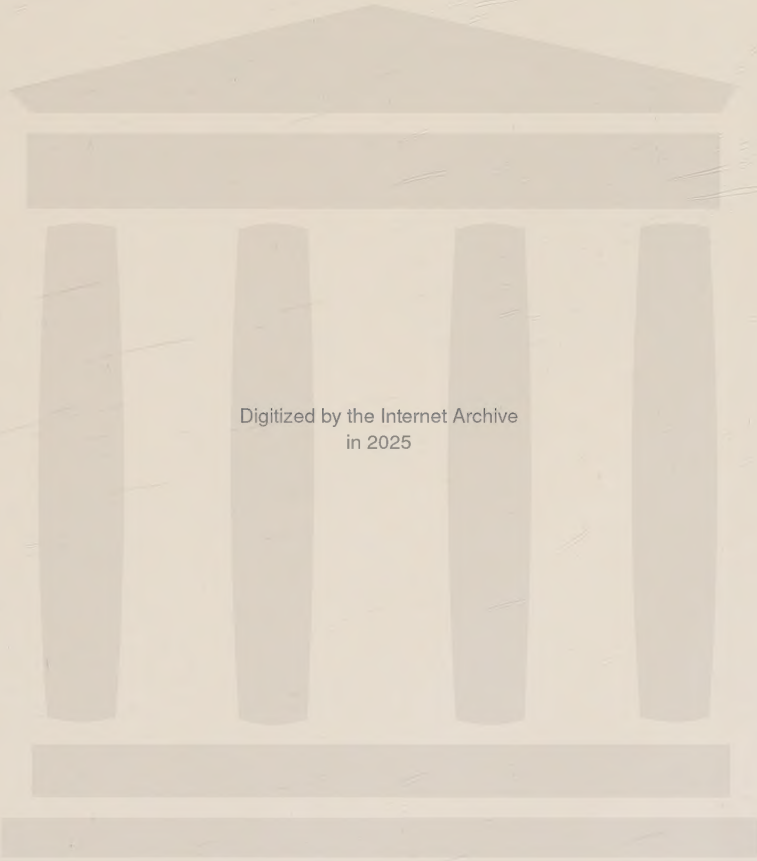
P. B. Cornwell, M.Sc., A.R.C.S., D.I.C., A.I.C.T.A.

should read

P. B. Cornwell, M.Sc., A.R.C.S., D.I.C., D.T.A.

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Cacao Breeding: Controlled pollination

ANNUAL REPORT
of the
WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1954-55

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MANAGING COMMITTEE

At 31st March 1955

CHAIRMAN

S. J. E. Southgate .. Chief Secretary, West African Inter-Territorial Secretariat.

MEMBERS

J. H. Asafu-Adjaye .. Gold Coast.
H. H. Croucher .. Director of Agriculture, Western Region, Nigeria.
J. Dixon Principal Assistant Secretary, Ministry of Agriculture, Gold Coast.
B. E. Dwira Gold Coast Cocoa Marketing Board.
E. A. Haizel Gold Coast Cocoa Marketing Board.
E. W. Leach Director of Agriculture, Gold Coast.
C. J. Mabey Permanent Secretary, Ministry of Natural Resources and Social Services, Federation of Nigeria.
Hon. A. Obisesan, O.B.E. Federation of Nigeria.
A. Pickles Acting Director, West African Cocoa Research Institute.
E. A. Sanda, O.B.E. .. Federation of Nigeria.
J. M. Waterston .. Acting Director of Agricultural Research, Federation of Nigeria.

SENIOR STAFF

At 31st March 1955

Administrative Staff

DIRECTOR	.. (vacant)
DEPUTY DIRECTOR ..	.. A. Pickles, M.SC., A.I.C.T.A. (Acting Director).
SECRETARY	.. G. H. Neal, F.I.A.C., F.R.S.A., F.C.T.C.

Tafo Station

ENTOMOLOGISTS	.. H. R. Mapother, B.A., B.SC., A.R.I.C. (Insecticides Chemist). D. J. Taylor, B.SC., DIP.AGRIC.SCI., D.T.A. P. B. Cornwell, M.SC., A.R.C.S., D.I.C., A.I.C.T.A. F. Raw, B.SC., PH.D. F. E. Decker (Senior Assistant Specialist).
PLANT PATHOLOGISTS ..	.. W. T. Dale, M.SC., A.I.C.T.A. T. W. Tinsley, B.SC., PH.D. A. L. Wharton, B.SC., DIP.AGRIC.SCI., D.T.A. G. Usher, B.SC., DIP.AGRIC.SCI., D.T.A.
BOTANISTS	.. J. F. Archibald, M.SC., F.R.H.S. A. D. McKelvie, B.SC., DIP.AGRIC.SCI., D.T.A.
PLANT BREEDERS	.. H. H. Rogers, B.SC., DIP.AGRIC.SCI. R. Knight, B.SC., DIP.AGRIC.SCI., D.T.A.
SOIL CHEMIST	.. S. N. Adams, M.A., D.PHIL.
BIOCHEMIST	.. Miss E. Margaret Holden, B.SC.
AGRONOMISTS	.. R. J. Benstead, N.D.A., C.D.A. R. Wickens, M.A., DIP.AGRIC., D.T.A.
MAINTENANCE ENGINEER ..	.. C. Alderson, D.S.O., B.SC., M.I.M.C.E.
STATION MANAGER ..	.. S. E. Ntim-Kwafo.

Ibadan Sub-Station

OFFICER-IN-CHARGE ..	.. J. Nicol, B.SC.(FOR.) (acting).
PLANT PATHOLOGISTS ..	.. R. M. Lister, B.SC., DIP.AGRIC.SCI., D.T.A. J. M. Thresh, B.SC., A.R.C.S.
ENTOMOLOGIST	.. R. G. Donald, B.SC., A.I.C.T.A.

PART I. ADMINISTRATION

This report of the West African Cocoa Research Institute covers the period 1st April 1954 to the 31st March 1955. With the exception of a few weeks in April 1954, Mr A. Pickles, Deputy Director, was in charge of the Institute's activities during the whole of the period under review.

LEGISLATION

In the Annual Report for 1953-54, reference was not made to the West African Cocoa Research Institute (Amendment) Ordinance, 1954, which received the Royal Assent on the 18th March 1954, shortly before the conclusion of the Institute's administrative year. It appears desirable that this omission should be rectified here.

The amendments provide that the Governments of the Gold Coast and Nigeria shall be consulted by the Secretary of State when appointing a Director of the Institute and a Chairman of the Managing Committee and that their tenure of office during the pleasure of the Secretary of State shall also be subject to consultation with those Governments. In place of four members of the Managing Committee, each of the Governments may now nominate members not exceeding five in number; in the case of the Gold Coast, two of the members shall be members of the Cocoa Marketing Board who have been recommended by the Board for nomination. Finally, the Ordinance provides that offices under the Institute or the Managing Committee may be declared pensionable offices under the Gold Coast Pensions Ordinance, 1950.

The West African Cocoa Research Institute (Pensionable Offices) Order, Gold Coast, 1955, declared a schedule of offices at the Institute to be pensionable for the purposes of the Pensions Ordinance; the pensionable status of the Institute's officers has thus been regularised.

MANAGING COMMITTEE

Mr S. J. E. Southgate, who assumed charge of the West African Inter-Territorial Secretariat as Chief Secretary on 16th June 1954, was appointed Chairman of the Managing Committee.

Membership of the Managing Committee has undergone a number of other changes, partly as a result of the West African Cocoa Research Institute (Amendment) Ordinance 1954 and partly in consequence of constitutional and departmental changes in Nigeria.

The Hon. Nene Mate Kolé resigned his membership of the Committee and Messrs R. Johns, O.B.E. and R. F. A. Grey, O.B.E. relinquished their membership, the former on his retirement from the post of Inspector-General of Agriculture in Nigeria and the latter on his appointment as Secretary to the Governor-General and Council of Ministers of the Federation of Nigeria. The Gold Coast Government nominated Messrs B. E. Dwira and E. A. Haizel, both members of the Cocoa Marketing Board, to be members of the Committee and the Government of the Federation of Nigeria nominated Messrs R. W. Ellison (Permanent Secretary, Ministry of Land and Natural Resources), J. M. Waterston (Acting Director of Agricultural Research) and H. H. Croucher (Director of Agriculture, Western Region). Consequent upon re-arrangement of ministries in Nigeria, Mr Ellison was subsequently replaced on the Committee by Mr C. J. Mabey (Permanent Secretary, Ministry of Natural Resources and Social Services). The membership of the Committee as now constituted is shown on p. 7.

The Managing Committee met on two occasions during the period under review, viz. on the 10th and 11th November 1954 and the 24th February 1955. Both meetings were held at Tafo.

FINANCE

At the Fifteenth Meeting of the Managing Committee held in November 1954 it was observed with grave concern that the Institute's capital funds were becoming depleted and were, in fact, barely sufficient to finance the work of the Institute for another five years. Before the subsequent meeting, however the Institute received endowments of £1,346,880 from the Gold Coast Marketing Board and £605,120 from the Nigerian Board. At the present rate of expenditure the total sum so received is sufficient to guarantee the Institute's continuation for another twenty years.

At the time of writing, the audit of the accounts for the financial year 1954-55 has not been completed, and final details of the financial transactions for the year cannot be communicated. It is intended, however, to publish a Financial Statement for the year 1954-55 as a Supplement to this Report when the audited accounts are received.

The following statement, which is subject to modification in the light of the Auditors' Report, is submitted as an interim indication of the Institute's expenditure during the year.

<i>Head of Expenditure</i>	<i>Original Estimate</i>	<i>Revised Estimate</i>	<i>Estimated Actual Expenditure</i>
<i>Recurrent</i>	£	£	£
Personal Emoluments ..	63,920	61,192	51,756
Other Charges ..	115,140	116,928	106,680
Sub Total ..	179,060	178,120	158,436
<i>Non-recurrent</i>			
Extraordinary Capital Expenditure ..	38,910	48,651	19,485
<i>Special Expenditure</i>			
Nigerian Cocoa Survey ..			2,549
Total ..	217,970	226,771	180,472

The following statement of revenue for the year must similarly be regarded as tentative pending the audit report.

<i>Head of Revenue</i>	<i>Original Estimate</i>	<i>Revised Estimate</i>	<i>Estimated Actual Revenue</i>
	£	£	£
Sale of Cocoa ..	5,436	4,840	4,041
„ „ other produce ..	170	170	185
Rents ..	3,050	3,050	3,276
Conservancy Fees ..	214	214	220
WACRI Booklet ..	2,000	2,000	—
Miscellaneous ..	100	100	540
Sub Total ..	10,970	10,374	8,262
Dividends and Interest ..	33,000	33,000	36,579
Total ..	43,970	43,374	44,841

STAFF

Senior Staff

The post of Director, vacant since the 6th August 1954, is to be filled by the appointment of Mr J. Lamb, O.B.E., M.Sc. Mr Lamb, at present Director of the Tea Research Institute of Ceylon, is expected to assume his new duties in October 1955.

Dr J. A. R. MacLean, Chemist, resigned his appointment in August 1954 to take up employment in the United Kingdom. Dr T. W. Tinsley, Plant Pathologist, went on final leave in March 1955 on completion of his term of attachment to the Institute, prior to reverting to his substantive appointment at Rothamsted Experimental Station. Mr R. Knight, Plant Breeder, has accepted an

appointment at the Waite Agricultural Research Institute of the University of Adelaide, South Australia and went on final leave in March before taking up his new duties. Major C. Alderson, D.S.O., Maintenance Engineer, went on leave on the 30th March 1955, prior to retirement from the Institute.

Grateful acknowledgement is again due to the Director of the Rothamsted Experimental Station for releasing two of his research officers on secondment to the Institute. Miss E. Margaret Holden, Biochemist, arrived in October 1954 on secondment for two tours to work on the biochemical aspects of virus problems. Dr F. Raw, Entomologist, came for one tour in November 1954 and is working on capsid problems.

Mr J. Nicol, Senior Entomologist, was posted to the Ibadan Sub-Station in December 1954 as Acting Officer-in-Charge.

The senior staff list at the 31st March 1955 is given on p. 8.

Junior Staff

The organisation of the Institute's junior service presents many difficulties and, at the present time, it is far from satisfactory. For many years, by unofficial arrangement, the higher appointments in the junior service were filled, either by the promotion of officers serving in the Institute or by transfer of officers, on promotion or otherwise, from Gold Coast Government departments. In a similar way, experienced officers of the Institute, who were qualified for promotion but for whom no immediate promotion prospects existed in the Institute's service, were frequently given the opportunity of transferring to a Government Department. The creation of an independent Gold Coast Civil Service, however, has brought to an end such transfers on an inter-departmental basis.

It must be admitted that the Institute has only a limited number of posts in the higher branches and promotion prospects in the Institute are definitely inferior to those in Government service. The Institute's junior staff, however, possess the same qualifications and draw the same salaries as the corresponding officers of Government and, with the lack of promotion prospects, appointments with the Institute are less attractive than are corresponding ones with Government. As a result, there tends to be a drift from the Institute's junior service to Government whenever new Government appointments are advertised and, at the same time, the Institute cannot compete with Government in attracting new entrants with the requisite qualifications nor can it fill higher vacancies by inter-departmental transfer. The Managing Committee is aware of the situation and has directed that a practical solution to this problem be sought and reported upon.

The approved establishment of junior staff and the strength at the 31st March 1955 are as follows:

<i>Category</i>	<i>Approved Establishment</i>	<i>Strength at 31/3/55</i>
Higher Executive Officers ..	2	2
Executive Officers	2	1
Clerical Officers	9	8
Clerical Assistants	21	16
Senior Technical Assistants	3	3
Technical Assistants	34	24
Stenographer Grade I	1	1
Artisans	3	1
Health Staff	2	2

Unestablished Staff and Labour

The average daily attendance of unestablished staff and labour during the year at the main station at Tafo was as follows:

April 1954 ..	686	October 1954 ..	685
May	686	November	688
June	681	December	689
July	686	January 1955 ..	684
August	689	February	695
September	689	March	701

Health

The health of the senior and junior established staff was good and very little working time was lost from illnesses or casualties. One distressing accident occurred when a senior officer was accidentally splashed with fuming nitric acid. Despite the fact that first-aid materials were to hand and were promptly applied and that the injuries were fortunately superficial, the officer was detained in hospital for some weeks.

Five cases of 'sandfly fever' occurred amongst European residents. It is gratifying to be able to record rapid and favourable response by patients to treatment with the antibiotic chloromycetin, and there is no doubt that such treatment would shorten the course of the fever if early diagnosis could be made and if the remedy were readily available.

The Institute maintains a medical centre under the charge of a qualified male nurse for first-aid, for the treatment of minor ailments and for such routine treatment of chronic cases as can be effectively administered. The following cases were treated:

Venereal Diseases (including			
Yaws)	..	..	1,830
Malaria	..	..	1,493
'Sandfly fever'	..	..	25

Diseases of the Alimentary Tract	87
Helminthic diseases	34
Diseases of the respiratory tract	341 (Pneumonia 14)
Skin diseases (including scabies)	233
Abscesses, boils and swellings ..	156
Acute infectious diseases	
(chicken pox)	7
Conjunctivitis and otitis ..	210
Dental caries	53
Hernia	3
Chronic Ulcer	207
Paralysis	2
Motor etc. accidents	17
Snake bite	2
Other bites and stings ..	25
Fractures	1
Lacerations and wounds ..	281
Foreign body in eye, ear or nose	15
Superficial and Skin injuries ..	8
Burns	9
Total cases treated	5,039

This list does not purport to indicate the medical history of the Institute's staff during the year. The cases listed include an indeterminate number of patients from New Tafo and the surrounding area. In addition, cases of acute illness or major injury may be referred direct to the hospitals without treatment at the centre.

PUBLICATIONS

Mimeographed Quarterly Reports were issued as soon as possible after the end of each quarter.

The booklet *WACRI and the Cocoa Farmer*, a popular illustrated account of the constitution, aims and work of the Institute, was published during the year, an edition of thirty-one thousand copies being called for.

The first two numbers of a new series of Technical Bulletins were issued shortly before the close of the period under review. Bulletin No. 1, by D. J. Taylor, is entitled 'A Summary of the Results of Capsid Research in the Gold Coast'; the second, which also deals with capsids, is 'Capsids and Capsid Control in the Belgian Congo, with especial reference to Lukolela Plantations', by J. Nicol and D. J.

Taylor. The Bulletins are designed primarily for the information and guidance of those responsible for agricultural education and extension work in West Africa.

Several scientific papers by members of the staff were accepted for publication in professional journals but, owing to the pressure on space to which technical publications are subject, none of these has yet appeared.

SCHOLARSHIPS AND TRAINING

It is the expressed policy of the Institute to recruit suitably qualified Africans to its senior staff as research workers and, in order to provide facilities for promising students to acquire the research training necessary, two post-graduate scholarships are offered to Africans holding a good degree in the appropriate sciences or in Agriculture. Unfortunately students of the requisite calibre seldom apply for these awards, in spite of the wide publicity given to them in West Africa and through the students' organisations in Great Britain and the United States. During the current year, only one applicant appeared to have the necessary qualifications for an award. As however, this applicant is already under bond to serve as a teacher in respect of an undergraduate scholarship, it is unlikely that an award can be made.

The Institute also provides annually for the training of two members of the unestablished staff to qualify them for appointment as Technical Assistants on its junior pensionable staff. Selection is by competitive examination conducted by the Department of Agriculture of the Gold Coast and the examination and the standard required are identical with those for prospective officers of that Department. Successful candidates take a three-year course of training which comprises one year's instruction at the Kumasi College of Technology, one year's practical work on an agricultural station and one year at the Kumasi Agricultural Training Centre. During the year 1954-55 two awards were made, the successful candidates being Messrs B. Bentum (Chemistry Division) and E. O. Yeboah (Station Management).

TOURING AND VISITS

The Acting Director, accompanied by Dr T. W. Tinsley, flew to London in August 1954 to attend a meeting of the Cocoa Research Sub-Committee of the Committee for Colonial Agricultural Animal Health and Forestry Research, at which the Institute's Research Programme for the year 1954-55 was discussed. The opportunity was also taken to visit Messrs Cadbury Brothers works at Bournville, Rothamsted Experimental Station and East Malling Research Station for technical discussions. In February 1955, the Acting Director again



Soil Map, Tafo Station. (Redrawn from a map by C. F. Charter)

LEGEND

KOFORIDUA	SERIES		ASAFO	SERIES	
W.A.C.R. I.	SERIES		JUMAPO	SERIES	
NANKESSE	SERIES		NYANTINA	SERIES	
SUHIEN	SERIES		ADODOWA	SERIES	
AKODUM	SERIES		DENSU	SERIES	
BEIRA	SERIES		ROCK OUTCROPS		

flew to England for another meeting of the Sub-Committee and he was accompanied by Mr H. H. Rogers. The Research Programme for the year 1955-56 was discussed and was recommended for the approval of the Secretary of State.

Dr T. W. Tinsley represented the Institute at the Second International Virus Conference in Wageningen and at the Eighth International Botanical Congress in Paris in June and July 1954 respectively. The Institute was represented at the Soils Conference of the Committee for Technical Cooperation in Africa South of the Sahara and at the Fifth International Congress of Soil Science by Dr S. N. Adams. Both Conferences were held in the Belgian Congo in August and September 1954.

Routine visits were made by various officers to places in the Gold Coast in connection with field experiments and surveys. Mr McKelvie, Plant Physiologist, visited the British Cameroons in May 1954 to investigate the leafless twig 'disease' of cacao. In February 1955 Mr D. J. Taylor, Entomologist, visited Sierra Leone to examine the status of Capsid pests of cacao there. Dr F. Raw and Mr R. J. Benstead visited Nigeria in March, the former to examine severe capsid damage in the Western Region and the latter to advise on the extension of cacao cultivation in the Eastern Region.

VISITORS

The number of visitors to the Institute continues to increase and it is evident that special arrangements are necessary to cater for them. At present, oversea visitors are conducted round the station by the Director or by members of the senior staff and, in many cases, this entails serious interruption of their work. The Managing Committee have provided in the estimates for 1955-56 for the appointment of a Public Relations Officer, part of whose duties will be to attend to the

reception and entertainment of visitors. An extension to the Rest House has also been approved so that more visitors requiring to spend one or more nights at the Institute can be accommodated.

Parties of farmers, students and teachers from the Gold Coast continue to be organised and conducted by the Department of Agriculture. Two parties from Nigeria visited the Institute in August 1954 and thanks are again due to the Gold Coast Department of Agriculture who arranged for their accommodation and board.

Mr J. Lamb, O.B.E., Director-designate of the Institute, paid a brief visit to Tafo from the United Kingdom in February 1955.

On the invitation of the Institute, Dr. C. B. Williams, F.R.S. spent some weeks at Tafo in April 1954 for the purpose of advising on capsid investigations. Dr E. W. Russell of the School of Agriculture, Oxford, also accepted the Institute's invitation in September to advise on soil and fertilizer studies. Mr F. C. Bawden, F.R.S., of Rothamsted Experimental Station, spent several days at the Institute in the course of his enquiries into the swollen shoot problem of Nigeria.

The Hon. K. O. Mbadiwe, Nigerian Minister of Land and Natural Resources, accompanied by Mr E. W. Ellison, Permanent Secretary of the Ministry, paid a visit of two days duration in April 1954. In October, the Gold Coast Minister of Agriculture, the Hon. J. A. Jantuah and Mr T. A. Mead, Permanent Secretary, spent several days examining the work of the Institute.

Visitors from the Colonial Office included Sir Hilton Poynton, Mr R. J. Vile, Mr R. W. Piper and Mr J. D. B. Shaw.

Representatives of marketing and manufacturing interests included Mr Kankam Boadu of the Gold Coast Cocoa Marketing Company Limited, Mr John Cadbury, Mr Adrian Cadbury, and Messrs Hemphill, Hegarty, Wregg and Zeman, who represented manufacturers of the United States.

Mr James F. Gehr, who was enquiring into the production of West African cocoa on behalf of the U.S. Department of Agriculture, spent a day at the Institute in September.

Other visitors included Lord Harlech, seven officers from the Imperial Defence College and Mr A. H. Cresswell, a cocoa planter from New Guinea.

Numerous visits continued to be paid by senior officers of the Gold Coast Department of Agriculture and other Government Departments.

The Ibadan Sub-station has also had its share of visitors and had the privilege of welcoming His Excellency the Governor, the Prime Minister and the Minister of Agriculture, Western Nigeria.

LAND MATTERS

There has been considerable delay in securing formal title to some of the lands required by the Institute and of which it had been in actual occupation for some time. These irregularities appear now to have been brought to an end by deeds of conveyance, registered by the Lands Department on the 20th August 1954 and the 8th February 1955, which respectively concern additional land for junior staff quarters and for the reservoir site. The area involved comprises a little over eighty-six acres and was generously donated to the Institute by the Stool of Tafo.

PART II. MANAGEMENT AND MAINTENANCE

GENERAL

As indicated in the last Annual Report, the Division of Station Management was to absorb the functions of the Maintenance Division progressively. This process was completed in April 1955, when the Station Manager assumed responsibility for the waterworks. In view of his greatly increased responsibilities, two additional Technical Assistants were appointed to assist the Station Manager; one is in charge of the mechanical workshops and the waterworks, while the other attends to buildings.

CONSTRUCTION WORK

Although the main construction programme at Tafo was completed some years ago, it has been necessary to embark on further construction work to provide housing and laboratory accommodation for additional members of the senior staff who are likely to be appointed in the near future. A new two-bedroomed bungalow has been erected and furnished; this has been built on the same basic design as the Rest House in Accra, with some slight modifications which experience has shown to be desirable. An additional entomological laboratory, consisting of three inter-communicating rooms, has been built and equipped. In addition, the Tafo Rest House has been extended by the addition of two bedrooms and a bathroom.

At Ibadan, three new bungalows for senior staff were completed; a store building and two garages were also built during the year. Tenders have been invited for the erection of the Institute's new laboratory at Moor Plantation.

MAINTENANCE OF BUILDINGS

Repairs were effected to nineteen senior staff bungalows and to 254 quarters in WACRI Village. Eight bungalows were repainted inside

and out and 147 junior staff houses were whitewashed. Four guest chalets, the Rest House, Medical Centre and reservoir pump houses were repainted and the roof of the Crown Agents' Store was repainted.

MAINTENANCE OF VEHICLES AND MACHINERY

A technical assistant with European training was appointed in the last quarter of the year to take charge of the workshops and to be in charge of the waterworks machinery. As a result of this appointment, all the Institute's vehicles, some of which had been out of use for some time, were reconditioned and put to effective use.

The mileage covered by vehicles and the consumption of petrol and oil were:

Mileage covered	..	..	94,567
Petrol	..	..	6,581 gallons
Oil	..	..	158 gallons.

MINOR WORKS

A store building for volatile chemicals was erected near the Crown Agents' Store. This was built on a design modified from the Public Works Department's pattern for a small petrol store and was constructed of concrete blocks lined with heat-insulating material. The building still leaves much to be desired as the interior remains hot, with little temperature fluctuation and the only advantage to be gained from its use at present is that the risks of accident and fire are minimised.

One bedroom wing in each of bungalows 3 and 4 was mosquito-proofed; nurse's quarters were repaired and extended; an open shed was built for storing timber stocks and the timber yard was protected by a close-paling fence.

WATER SUPPLY

The installation has worked satisfactorily throughout the year. Weekly samples of water have been submitted regularly for testing by the Water Examination Specialist of the Gold Coast Government and, in December 1954 and January 1955, coliform organisms were detected in small quantity. Prompt action was taken and the pollution was eliminated and has not since recurred. In January also, minute crustacea were found in certain sections of the mains, particularly in WACRI Village. This was probably due to the difficulty of scouring the pipes thoroughly in very dry weather. After thorough scouring and increasing the chlorine content of the water, the organisms disappeared and no further trouble of this nature has occurred.

Exceptionally dry weather occurred in January and February and, for twenty-two days, the inflow at the head of the reservoir ceased entirely. At the same time, water consumption increased markedly, largely owing to the amount taken from stand-pipes by villagers from New Tafo, and on some days the consumption exceeded the nominal capacity of the pumping and filtration plant of 30,000 gallons per day. Despite this, the level of the reservoir fell by only six inches and quickly rose to the level of the spillway when rain occurred.

The average daily consumption for each month of the year and the corresponding rainfall recorded in the reservoir area are shown in the following table:

			<i>Average Consumption (gallons)</i>	<i>Monthly Rainfall (inches)</i>
1954				
April	..	..	18,970	6.64
May	..	..	20,000	6.56
June	..	..	18,370	8.15
July	..	..	19,600	1.01
August	..	..	22,400	1.05
September		..	20,310	6.68
October	..	..	18,900	9.84
November		..	22,300	1.38
December	..	..	24,600	1.35
1955				
January	..	..	25,230	0.55
February	..	..	25,500	4.81
March	..	..	19,800	7.23

ROADS

In February 1954, a contract was let to provide for tarring the main roads of the residential area, of the headquarters environs and the major road of access to the square mile. In all, 4,177 yards of road surface were treated, at a cost of £3,383 7s. 5d.

SUPPLY OF VEGETABLES

The vegetable garden continued to produce fresh vegetables for sale to the staff. It has been difficult to produce a great variety of produce, but supplies of staples such as cauliflower, beans, salads and spinach have been well maintained. A total of 6,180 lb. of green vegetables was produced, an increase of 253 lb. over last year's production. In addition, 23,500 cobs of maize, 7,900 lb. of Chinese yams and 1,790 lb. of paddy rice were produced for staff use.

TABLE I
Yield of recorded plots, Old Station

Date of Picking		Total Pods		% Pods discarded	Pods fermented	Wet wt. of Beans (lb.)	Dry wt. of Beans (lb.)	% Dry to Wet weight	Pods per lb. dry Cocoa	Pods issued for Seed
		Harvested	Discarded							
1954										
July 5-20	..	..	892	6.4	12,615	3,025.1	1,194.25	39.48	10.6	389
" 26-Aug. 16	..	..	3,324	7.2	41,646	9,784.8	4,116.61	42.07	10.4	930
Total Minor		..	4,216	7.1	54,261	12,809.9	5,310.86	41.46	10.4	1,319
Aug. 23-Sep. 14		..	6,434	11.1	49,289	10,656.7	4,400.23	41.29	11.2	2,176
Sep. 21-Oct. 25	..	..	7,283	9.6	68,169	14,467.1	5,972.07	41.28	11.4	200
Oct. 25-Nov. 8	..	..	3,521	10.3	30,529	6,237.8	2,627.41	42.12	11.6	10
Nov. 15-Dec. 8	..	..	30,198	6.7	28,134	5,841.6	2,470.99	42.30	11.4	29
Dec. 20-Jan. 25	..	..	2,035	5.7	29,030	5,961.1	2,580.58	43.44	11.2	1,880
Jan. 31-Feb. 7	..	..	1,880	25.6	2,520	486.4	217.05	44.62	11.6	18
Total Main..		..	22,033	9.4	207,669	43,650.7	18,277.33	41.87	11.4	4,313
1954/55		..	26,249	8.9	261,930	56,460.6	23,588.19	41.78	11.2	5,632
1953/54		..	43,019	11.0	308,226	64,259.6	26,332.21	40.98	11.7	41,466

PART III. COCOA PRODUCTION

TAFO STATION

The total amount of cocoa sold was 66,368 lb., as compared with 80,610 in the previous year, a decline of 14,242 lb. or 17.6 per cent. Part of this decline is due to producing areas being taken over for experimental purposes, but the recorded plots of the Old Station showed a decline in production of 19.4 per cent. compared with the previous year, which was itself 9.4 per cent. below 1952-53.

Details of the crop from the recorded plots of the Old Station, which total 63.69 acres, are given in the preceding table:

A comparison between the present crop, that of last season and the seventeen-year mean is given in Table 2.

TABLE 2

Season	Pods Harvested	Percentage pods discarded	Total wet weight of beans (lb.)	% dry to wet weight	Pods per lb. dry cacao	Yield per acre
1954-5	.. 293,811	8.9	56,461	41.8	11.2	378.3
1953-4	.. 392,711	11.0	64,260	41.0	11.7	469.1
17-year mean	.. 531,396	11.5	97,596	41.2	11.4	613.1

OUT-STATIONS

Work on the out-stations has been concerned with general maintenance and the adjustment of shade and cacao density. Young forest trees which were fostered during the establishment period have been thinned selectively by the removal of those which provide too dense a shade for mature cacao and the shade position can now be considered satisfactory.

Progressive thinning of the cacao by the removal of weakly trees has resulted in a stand of 600 to 700 trees per acre on the areas of advanced growth and thinning continues on the remaining areas when the cacao canopy integrates.

Yield from selected areas on the Nankese, Kukua and Koransang substations is tabulated in the accompanying table.

TABLE 3

Substation	Acreage	Yield Pods		Estimated yield lb. dry cocoa per acre	
		1953-54	1954-55	1953-54	1954-55
Koransang ..	3.0	8,197	9,990	228	297
Kukua ..	5.0	24,745	26,241	412	469
Nankese ..	3.5	8,331	10,841	197	277

Capsid control has been effective on all substations except Akwadum, where all badly damaged areas have been coppiced as a method of regeneration.

SWOLLEN SHOOT INCIDENCE

The rate of infection in mature cocoa on the Old Station has remained fairly constant, being 1.96 per cent. of the tree population as compared with 2.04 per cent. in 1953-54. On the Square Mile the infection rate fell from 2.08 to 1.21 per cent. during the same period. Only two infected seedlings were discovered in experimental areas of the Tafo station as compared with 112 seedlings from areas of young cocoa scattered among the mature trees of the Old Station. These figures illustrate once again the advantage to be derived from block-replanting as compared with scattered and progressive rehabilitation amongst old cocoa in areas where the rate of infection is high.

At the out-stations, the incidence of disease has remained low except at Adonkwanta; here the higher incidence seems definitely to be due to the presence of heavily infected farms adjoining, where control measures have not yet been applied. Details are shown in Table 4.

TABLE 4
Swollen shoot incidence at out-stations

<i>Station</i>	<i>No. of trees infected</i>	
Akwadum ..	..	8
Nankese ..	..	nil
Koransang ..	..	7
Kukua ..	..	16
Adonkwanta ..	..	129

PART IV. IMPROVED PLANTING MATERIAL

The superiority in vigour and yield over West African Amelonado of certain Upper Amazon selections has been noted in many previous Annual Reports. It will be recalled that these selections were introduced into West Africa by Posnette from Pound's original collection in Trinidad. In 1948 the Commission of Enquiry into the Swollen Shoot Disease of Cacao in the Gold Coast were impressed by the performance of these selections and reported: 'The Commission . . . urges that every possible method be used to speed up the production of the improved selections now available at the West African Cacao Research Institute in small quantities only.'

In consequence of this recommendation, the Institute increased its own plantations of Upper Amazon trees and released seedlings, seed, budwood and rooted cuttings to the Departments of Agriculture of the Gold Coast and Nigeria for the foundation of nurseries from which farmers might subsequently be supplied with planting material.

No releases were made to farmers, however, as the quality of the cocoa which could be prepared from the produce of these selections was unknown. Small samples of fermented cocoa from individual types were prepared and were submitted to trade organisations in

Great Britain and the United States for appraisal of the flavour of the resulting chocolate. In the absence of a perfectly consistent method of fermenting the beans, no final opinion as to their acceptability could be given; indeed, replicate samples of one selection sometimes differed more from each other than from another selection.

It was finally agreed with the manufacturers' taste panels that, instead of preparing samples from individual selections, bulk samples should be prepared from trees of the same parentage group. In this way it was possible to ferment the samples by the ordinary large-scale methods instead of by specialised laboratory methods and to prepare chocolate in the factory for appraisal.

In September 1954 the representatives of the British and United States chocolate industries independently expressed the opinion that the flavour of all the samples submitted to them was acceptable, as being in the West African Amelonado flavour range. Two of these, however, were not acceptable on account of their undesirably small beans. The manufacturers saw no objection to general planting of the other selections whose flavour they had approved.

As a result of this finding, the Departments of Agriculture in Nigeria and the Gold Coast have decided to supply farmers with seed from the progeny of the approved selections as rapidly and on as large a scale as possible. Already in April 1954 the Institute was supplying the Nigerian Western Region Department of Agriculture with all available pods of Upper Amazons for planting purposes—originally for planting by the Western Regional Production Development Board. Damaged pods unsuitable for export, but fit for the supply of seed for immediate planting, were released to the Gold Coast Department. In the course of the year, Western Nigeria received 6,224 pods of approved types and the Gold Coast 1,557. At the fifteenth Meeting of the Managing Committee it was agreed that the F_2 generation of Upper Amazons should be made available in 1955 only to the Governments of the Gold Coast and Nigeria and that supplies should be allocated in the proportions in which their Marketing Boards contribute to the support of the Institute, i.e., Gold Coast 69 per cent. and Nigeria 31 per cent.

The selections which are now regarded as 'approved' types for propagation are:

T60, 63, 65, 72, 73, 76, 79, 82, 85 and 87.

There can be no doubt that this development is of very great importance and may have far-reaching effects on cocoa production in West Africa. At the same time it should be realised that other new varieties, the first products of the Institute's breeding programme, which are now undergoing trial, give promise of significantly surpassing the best of the Amazons in vigour and yield.

PART V. WEATHER SUMMARY

A. TAFO STATION

Figures for 1954 compared with 17-Year Means

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 17-Year Mean	91.4	93.7	93.2	93.7	92.3	80.2	87.0	86.5	88.0	80.7	90.5	90.7
" " " 1954	..	..	..	..	..	..	..	..	..	..	..	..
Lowest Shade Minimum 17-Year Mean	92	93	89	92	92	87	87	89	87	89	90	91
" " " 1954	59.4	61.4	65.9	66.2	66.7	66.1	65.9	65.1	66.6	66.6	65.2	62.7
Mean Relative Humidity 17-Year Mean	58	62	68	67	67	67	64	64	66	66	66	66
" " " 1954	86.1	83.7	81.9	80.8	81.7	84.9	86.2	86.1	85.3	83.3	81.5	84.1
Mean Relative Humidity (9.00 GMT) 1954	87.0	82.9	83.3	83.8	82.3	86.9	87.0	86.7	85.0	84.3	80.5	84.9
Mean Relative Humidity 17-Year Mean	55.1	52.6	55.6	58.7	63.3	69.1	69.7	69.0	70.9	70.8	65.3	61.2
" " " 1954	62.0	63.2	64.6	68.4	74.5	76.9	74.6	73.2	69.8	72.4	69.3	63.5
Rainfall in inches 17-Year Mean	1.63	3.76	5.96	5.81	6.93	8.43	5.39	2.62	6.24	8.73	4.20	2.26
" " " 1954	2.77	5.40	5.31	7.26	6.45	8.17	0.95	1.09	8.01	8.92	1.75	1.45
Number of Wet days 17-Year Mean	3.6	7.1	11.5	11.2	13.5	18.4	13.6	12.8	14.3	18.1	10.6	5.9
" " " 1954	7	8	9	13	14	21	13	14	18	21	11	6

Annual Rainfall Figures (in inches) 1938-1954

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	17-Year Mean
55-33	84.96	56.92	56.59	59.45	69.09	49.12	68.87	47.03	67.30	66.99	71.81	63.47	66.23	65.77	53.88	57.53	61.96	

Monthly Rainfall (in inches) and Number of Wet Days, April 1954-March 1955

<i>Month</i>	<i>April</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>Aug.</i>	<i>Sept.</i>	<i>Oct.</i>	<i>Nov.</i>	<i>Dec.</i>	<i>Jan.</i>	<i>Feb.</i>	<i>March</i>
Rainfall in inches	7.26	6.45	8.17	0.95	1.09	8.01	8.92	1.75	1.45	0.58	4.94	7.71
Number of Wet Days	13	14	21	13	14	18	21	11	6	4	9	15

B. OUT-STATIONS
Rainfall (in inches)

<i>Station</i>	<i>Jan.</i>	<i>Feb.</i>	<i>March</i>	<i>April</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>Aug.</i>	<i>Sept.</i>	<i>Oct.</i>	<i>Nov.</i>	<i>Dec.</i>	<i>Total</i>
Adonkwanta	1.05	5.25	2.91	12.66	6.83	7.24	.52	.77	9.27	8.89	4.06	1.18	60.63
Akwadum	3.49	3.51	4.66	5.97	8.77	5.86	.65	.53	9.04	7.68	2.78	1.20	54.14
Nankese	1.57	3.78	4.16	9.48	4.75	6.21	1.47	.91	5.00	10.49	3.76	2.43	54.01
Kukua	1.84	7.18	2.37	9.87	5.70	8.78	.94	.75	3.76	7.71	3.13	1.36	53.39
Koransang	1.58	5.97	2.12	8.66	6.20	8.13	1.40	.71	5.00	9.65	3.38	1.64	53.84

Annual Rainfall compared with Previous Years

<i>Year</i>		<i>Akwadum</i>	<i>Nankese</i>	<i>Koransang</i>	<i>Kukua</i>	<i>Adonkwanta</i>
1951	..	78.82	59.66	73.20	60.67	69.40
1952	..	56.44	57.95	60.28	51.37	76.01
1953	..	49.00	45.18	49.34	47.91	56.21
1954	..	54.14	54.01	53.84	53.39	60.63

PART VI. RESEARCH

TECHNICAL SUB-COMMITTEE

The Technical Sub-Committee consists of the Directors of the Departments of Agriculture of Nigeria and the Director of Agriculture, Gold Coast under the chairmanship of the Director of the Institute. Advisers may be, and usually are co-opted. The Sub-Committee's function is to consider all technical and scientific matters which may be referred to the Managing Committee and to present their conclusions to that Committee for their guidance.

During the year 1954-55 the Sub-Committee met on two occasions: at Tafo on the 9th November and at Ibadan on the 6th January. At the first of these meetings the main subject for discussion was the recommendation of the chocolate manufacturers of Great Britain and the United States of America that certain of the Upper Amazon selections should be regarded as commercially acceptable. The Sub-Committee agreed to recommend the release to farmers of the acceptable types, that types not acceptable to the industry should not be released to farmers but should nevertheless be retained by the Departments of Agriculture and the Institute for experimental and research purposes. It was further agreed that Upper Amazon cocoa should be bulked with Amelonado when offered for sale since any attempt at separation would be impracticable.

A basis for the allocation of planting material between the Governments served by the Institute was also agreed (see Part IV—Improved Planting Material).

The second meeting was mainly devoted to consideration of the draft Research Programme for the year 1955-56 (see Appendix, p. 105). The draft was considered in detail and, after some amendment, was recommended for the consideration of the Cocoa Research Sub-Committee of the Committee for Colonial Agricultural, Animal Health and Forestry Research.

ORGANISATION OF RESEARCH

The research work of the Institute follows a fairly detailed programme, drafted in consultation with the officers responsible for its implementation. Before its final acceptance, the programme is scrutinised by the Technical Sub-Committee, the Cocoa Research Sub-Committee to which reference was made above and by the Managing Committee and receives the approval of the Secretary of State for the Colonies.

While the programme is adhered to as closely as possible, some latitude in its interpretation and implementation is essential; new problems may be brought to light in following a given project and their solution may be necessary before the major line of work can be pursued further. Projects considered promising in the beginning may prove to be of little utility and must be discontinued. Work on some problems may have to be postponed through delays in the delivery of essential equipment. Thus, while most of the problems set out in the Research Programme for 1954-55, as shown in Appendix II of the last Annual Report, were actually studied, some items were added while others were deleted or postponed. The following modifications were found necessary during the course of the work. Virus Research—items (*h*) and (*i*) were discontinued and a new item was added on the resistance and tolerance of some Upper Amazon types of cacao. Mealybug Studies—two items were added to provide for the study of attendant ants and for the examination of the role of winged ants in mealybug dispersal. In the absence of a chemist for the greater part of the year, work on the chemistry of mealybug secretions was postponed. Capsid Studies—(*c*) and (*d*) were postponed until the necessary apparatus was delivered; a new item 'cultural control' was introduced to provide for the study in Gold Coast conditions of a method of capsid control which is highly successful in the Belgian Congo. Cacao Fermentation and Quality—again in the absence of a chemist, no work could be carried out on the chemistry of fermentation or on the factors affecting variation in the fat and alkaloid content of beans. The study of 'purple beans' was postponed until essential equipment could be obtained. In addition to the ten Upper Amazon selections which were pronounced commercially acceptable by the manufacturers in Great Britain and the United States (*vide supra*, p. 84), two selections were acceptable from the point of view of quality but they were rejected by the British manufacturers on account of small bean size. One of these (T12, Scavina) approached the minimum acceptable dry-bean weight of one gramme according to previous observations and further investigation was made to see if there was any improvement in bean weight with advancing age of the trees or any variation according to season (*vide p.* 85).

In the Plant Breeding Programme it was found impossible to commence work on pollen storage owing to pressure of other work and the establishment of nucleus plots on agricultural stations was made an additional project to facilitate the large-scale production of improved varieties for release to farmers. In Nigeria, the technique of coppicing infected and suspect trees was found to be a valuable method of studying swollen shoot outbreaks and the programme was expanded to enable the appropriate studies to be made.

The problems arising from attack by pinhole borers chiefly affect Nigeria; they appear to be of minor importance in the Gold Coast. As the only entomologist on the Institute's staff in Nigeria was fully occupied with mealybug studies and as no cases of pinhole borer attack were reported in the Gold Coast, it was not possible to study these problems during the year, though the project remains on the programme.

It quickly became apparent that a fundamental study of 'shade' in cacao cultivation was a matter of first importance and a new section was added to the programme to provide for this.

The approved research programme for 1955-56, which includes such necessary modifications introduced during the prosecution of that for the previous year, is set out in full in the Appendix (p. 105). While the research establishment of the Institute continues to be classified in Divisions (Pathology, Chemistry, Agronomy, etc.), the adoption of an integrated research programme has led to increasing co-operation between members of different divisions and, to a large extent, divisional organisation is retained rather for convenience of business administration than for control of research.

VIRUS RESEARCH

The Host Range of Cacao Viruses. (T. W. Tinsley)

Virus infection in *Adansonia digitata* L.

Examination of baobab trees (*Adansonia digitata*) in the Gold Coast has shown that natural infection occurs in the savannah woodland lying north and south of the forest belt. It was thought at first that only one virus strain was infecting the baobabs but later work has shown that a complex of strains exists. The exact relationship of these strains to those isolated from cacao is not yet known, though some marked similarities in symptom expression have been noticed. No swellings were produced when the *Adansonia* strains were experimentally transmitted to cacao seedlings (by *Pseudococcus njalensis* Laing), indicating a possible relationship to such cacao strains as Kpeve or Alaparun. Protection experiments have been set up to investigate this.

No infected *Adansonia* trees have so far been recorded from the cacao areas in either the Eastern or Western Provinces, though a number of infected trees occur on the Accra Plains. A wide survey has been made in the cacao areas of Ashanti, with the co-operation of the Department of Agriculture. Almost every village in this area has at least one tree and in some villages as many as thirty were recorded. A total of 189 trees was examined for possible virus infections: three were found with leaves showing virus-like symptoms and samples were taken for insect-transmission tests, the results of which are not yet available. In the north of Ashanti, far from the nearest cacao, infection has been confirmed at Yabraso.

Adansonia digitata is particularly common in the Northern Territories and samples have been collected from as far north as Bawku. The original samples were collected in the dry season when the trees are almost defoliated. It was not possible therefore to diagnose infection by leaf symptoms, so insect-transmission tests were made from rooted cuttings. No positive transmissions have yet been recorded from this Bawku material, but infection has been confirmed at Wasipe, far outside the area of cacao cultivation. It seems unlikely that this has spread from outbreaks of swollen shoot in cacao because of the distance involved (approximately 140 miles in a direct line) and the natural barriers of the Volta and associated rivers. Therefore the inferences are either that the virus has spread to *Adansonia* from another host or simply that it is primarily a virus of that tree. Although the number of potential host species in the savannah zone is small, many of those that do occur are known to be susceptible to artificial infection with cacao viruses. These include *Sterculia setigera* Del., *Ceiba pentandra* Gaertn., and four *Corchorus* species. Natural infections in these hosts will have to be investigated before any further speculation in this direction can be made. On the other hand, if the virus found in *A. digitata* is regarded as being primarily associated with that species, it is of interest to speculate on its origin and subsequent relation to the swollen shoot disease of cacao. The distribution of *Adansonia* in Africa is very wide: it has been recorded from Senegal to Northern Transvaal, though the natural range is probably more restricted. The surveys carried out in the Gold Coast have shown that it is not native, being invariably associated with villages or neglected farm sites. A more natural habitat appears to be the Sudan-Savannah zone which extends from Senegal into Kenya and passes some distance north of the Gold Coast. It is not known whether natural infection occurs in *A. digitata* in this region, and the point is worth investigating as it could account for the presence of infected trees here.

The baobab tree is important as a source of food and medicine, which in part explains its wide distribution. These uses are well known

to the Northern Tribesmen and vernacular names for the tree are to be found in all their languages; but the tribes inhabiting the southern forest regions are, in general, unaware of the baobab's value and, in the few areas where it is used, the knowledge can be traced to associations with the North. The trees which occur in the forest regions and on the coastal plains have been planted, with very few exceptions, by Northerners on their migrations southwards. *Adansonia* will grow from seed or cuttings. Though there is no evidence that the virus is seed-transmitted in the usual sense, mealybugs have been found feeding inside broken pods on the exposed seeds, which could become infected in this way. Dissemination of the virus is inevitable when infected cuttings are propagated. Thus, it can be postulated that infection must have been brought into the Gold Coast from regions to the north. Much more work on the distribution of infected *A. digitata* trees is required before these points can be fully elucidated.

Virus infection in *Cola chlamydantha* K. Schum.

The distribution of infected *Cola chlamydantha* in the Gold Coast contrasts with that of *A. digitata*. The former is confined to the Western Province and grows in very close association with cacao. The high incidence of infected trees, a threat to cacao cultivation in this region, has been reported in previous Annual Reports. An attempt has been made to relate the distribution of infected *C. chlamydantha* to outbreaks of cacao swollen shoot virus. With the help of the Department of Agriculture the numbers of *C. chlamydantha* trees per acre in two areas of the Western Province have been mapped in detail. The distribution of virus-infected cacao in these areas is being studied.

Six virus strains have been isolated from *C. chlamydantha* trees growing in widely separated localities and their symptoms in cacao seedlings are being studied. All of them produce severe leaf symptoms and stem swellings in cacao, and some similarities have been noticed to virus strains isolated from mature cacao in the Western Province. Protection tests between strains from *C. chlamydantha* and some cacao strains are in progress.

Laboratory tests.

Studies on the experimental host ranges of the West African cacao viruses have shown that twenty-five species, all Tiliaceae, are susceptible to infection with one or more of the strains maintained at Tafo. A revised list of species tested for susceptibility, which supersedes those in previous Annual Reports is given in Table 5. Synonyms for some species are given in the Annual Report for 1953-54 (p. 11). Unfortunately that list contains several typographical errors, but they can be readily detected by comparison with Table 5.

TABLE 5

Species of Tiliales tested for Susceptibility

Susceptible	Susceptibility not shown
	Tiliaceae
<i>Corchorus aestuans</i> L.	<i>Christiana africana</i> DC.
<i>C. olitorius</i> L.	<i>Desplatsia deweyrei</i> (De Wild. et Th. Dur.)
<i>C. tridens</i> L.	Burret
<i>C. trilocularis</i> L.	<i>Glyphaea brevis</i> (Spreng.) Monachino
	<i>Grewia carpinifolia</i> Juss.
	<i>Triumfetta rhomboidea</i> Jacq.
	Sterculiaceae
<i>Cola chlamydanthra</i> K. Schum.	<i>Byttneria catalpifolia</i> Jacq.
<i>C. gigantea</i> var. <i>glabrescens</i> Brenan et Keay	<i>Cola caricaefolia</i> (G. Don) K. Schum.
<i>C. lateritea</i> var. <i>maclaudi</i> Brenan et Keay	<i>C. millenii</i> K. Schum.
<i>Erythropsis barteri</i> (Mast.) Ridley	<i>C. nitida</i> (Vent.) Schott et Endl.
* <i>Herrania balaensis</i> Preuss.	<i>C. verticillata</i> (Thonn.) Stapf ex A. Chev.
* <i>H. spp.</i> 'A' and 'B' (indet.)	* <i>Kleinhovia hospita</i> L.
<i>Pterygota macrocarpa</i> K. Schum.	<i>Mansonia altissima</i> (A. Chev.) A. Chev.
<i>Sterculia rhinopetala</i> K. Schum.	<i>Melochia melissifolia</i> Benth.
<i>S. setigera</i> Del.	<i>M. pyramidata</i> L.
<i>S. tragacantha</i> Lindl.	<i>Nesogordonia papaverifera</i> (A. Chev.) R.
* <i>Theobroma angustifolia</i> DC.	Capuron
* <i>T. bicolor</i> Humb. et Bonpl.	<i>Scaphopetalum amoenum</i> A. Chev.
* <i>T. grandiflora</i> K. Schum.	<i>Tarrietia utilis</i> Sprague
* <i>T. macrocarpa</i> Mart.	<i>Triplochiton scleroxylon</i> K. Schum.
* <i>T. obovata</i> Bern.	<i>Waltheria lanceolata</i> R. Br.
* <i>T. speciosa</i> Spreng.	<i>W. americana</i> L.
	Bombacaceae
<i>Adansonia digitata</i> L.	* <i>Bombax sessile</i> (Benth.) Bakh.
<i>Bombax buonopozense</i> P. Beauv.	(= <i>Pachira oleagina</i> Decne.)
* <i>B. malabaricum</i> DC.	* <i>Ochroma pyramidale</i> (Cav.) Urb.
<i>Ceiba pentandra</i> Gaertn.	

* Exotic species

The susceptibility of *Guazuma ulmifolia* Lam. (*Sterculiaceae*) reported in the 1953-54 Annual Report has not been confirmed and is now considered doubtful. No infections have been recorded in the tests made with species of the *Malvaceae* and *Euphorbiaceae*, which are related to the Tiliales. Many species of other families which occur in association with cacao have also been tested, with negative results.

Optimum Conditions for Transmission. (W. T. Dale)

In this study a critical examination is being made of the effect of variations in the essential processes involved in insect transmission on the success or otherwise of the spread of cacao virus. The essential processes are considered to be: (a) pre-infection starving of the vectors; (b) infection-feeding; (c) test-feeding. The effect of varying numbers of vectors is also being examined. So far the study has been confined to the New Juaben strain and, with few exceptions, to the vector *Pseudococcus njalensis* Laing.

One experiment only has so far been completed on the effect of variation in the pre-infection starving period and the results do not suggest that starving has any direct effect on transmission rate, since

43 per cent. transmission occurred with insects starved for 0 and 48 hours respectively, while starving for three hours resulted in only 25 per cent. transmission. It should be noted, however, that the starving time was only nominally as stated, since no account was taken of the time elapsing between placing the insects on the source of infection and the commencement of actual feeding. It is also possible that the period of infection-feeding was so great (sixteen hours) as to mask a possible effect of prior starvation.

Examination of the effect of varying the duration of the infection feed shows that vectors may acquire the virus in as little as two hours or even less. The optimum feeding time appears to be in the neighbourhood of sixteen to twenty-four hours and there is a strong suggestion that longer infection feeds reduce the subsequent transmission rate. If this is really the case, it is possible that prolonged feeding may induce the production in the insect of a virus-inhibiting substance, or that vectors may feed greedily at first, subsequently becoming replete and feeding only intermittently. Another possibility is that the test insects were affected by variations in temperature and humidity, for in only one experiment did the time schedule permit all the insects to be fed at the same time of day.

Variation in the test-feeding time showed vectors could often infect a healthy host after fifteen minutes' feeding. The infection rate rose rapidly with increasing feeding time up to one hour and, more slowly, up to four hours. When the insects settled rapidly, the optimum feeding time was two hours. These results are in accordance with those obtained by Posnette and Strickland (*Ann. appl. Biol.*, **35**, p. 53, 1948), and by Posnette and Robertson (*ibid.*, **37**, p. 363, 1950).

Posnette and Strickland (1948, *loc. cit.*) showed that the New Juaben virus could be acquired and transmitted by vectors in a total of seven hours. This showed that if a latent period occurs in the insect, it must be of very short duration. Nevertheless a brief latent period might explain the fact that fairly lengthy infection feeds are the optima. Further examination of this point by the employment of short source and test feeds with a starving period between them has so far produced inconclusive results, but virus has been acquired and transmitted by vectors in as little as five hours.

Experiments on the effect of the number of vectors used indicate that, under conditions presumed to be optimum, an Amelonado bean is almost certain to be infected by ten adults of *P. njalensis*. The results confirm the observations of Posnette and Robertson (*loc. cit.*) regarding the absence of a 'mass-action' effect with larger numbers of vectors. In other words, individual mealybugs do not inject sub-minimal doses of virus which can accumulate to produce infection when groups of these insects are used.

To investigate the effect of vector age, mealybugs at three stages of maturity were compared: first- and second-instar nymphs ('crawlers'), third-instar nymphs, and young adults, all used at the rate of three per test bean. Infection rates for all stages were of the same order, i.e., about 70 per cent. showing that under the conditions used all stages were equally efficient as vectors.

Mealybugs are still the only known vectors of cacao viruses. Posnette (*Ann. appl. Biol.*, **37**, p. 378, 1950; *Trop. Agric., Trin.*, **28**, p. 133, 1951) reported only negative transmission results with *Pseudococcus concavocerarii* James, but it was listed as a vector in the Annual Report for 1948-49, p. 20. The discrepancy prompted a further trial, which showed that the species is a vector of the New Juaben virus, though not an efficient one. Further attempts to transmit the Kpeve virus by *Ferrisia virgata* were unsuccessful (cf. Posnette, 1950, loc. cit.). Only preliminary trials have been made so far to compare the efficiency of different vector species. *F. virgata* proved much inferior to *P. njalensis* as a vector of the New Juaben virus, but seems unsuited to the method used (Posnette and Strickland, 1948, loc. cit.) because of the large amount of wax produced. The insects became entangled within the cone and few settled. *Planococcus citri* seems to have the same handicap and it may be difficult to obtain a fair comparison between these species and *Pseudococcus njalensis*.

Classification of Viruses and Virus Strains. (T. W. Tinsley)

Studies on the inter-relationships of isolates in the insectaries at Tafo, using protection tests and symptomatology, have made good progress.

Isolates from Olanla and Ilesha in Nigeria are related, but distinct from Offa Igbo isolates. From their symptoms, the Asalu and Alaparun isolates appear to be distinct; though neither produces swellings, their leaf-symptoms are quite different. The relationships of isolates from more recently discovered outbreaks are being studied in Nigeria.

So far, strains from Mampong, Nkawkaw, Pamen, Nsaba and Bisa, in the Eastern Province of the Gold Coast, all appear to be distinct. An isolate from Dawa belongs to the widespread and destructive New Juaben complex, which is also represented by isolates from Konongo in Ashanti and Kongodia in the Ivory Coast, where there are at least two other apparently distinct strains, those from Appompromou and Yakasse. The Bosumtwi, Side Nkawe and Okerikrom isolates from Ashanti are all, on present evidence, distinct. Twelve isolates from the Western Province of the Gold Coast are under investigation; and although well over a third of the necessary tests have been completed, no protection has yet been demonstrated, in spite of symptom similarities between many isolates.

An isolate from Peki, in the Trans-Volta area of the Gold Coast, resembles the Bisa strain, though that has more marked symptoms. No protection tests have yet been made. The Kpeve (mottle-leaf) virus from British Mandated Togoland, another of those producing only leaf symptoms, is very distinctive.

It is now believed that there are at least two distinct groups of viruses attacking cacao in West Africa. The presence or absence of stem and root swellings has been taken as a criterion for separating the two groups. The results of protection tests made between strains of these groups are not yet available, and it is not known whether they will support this division based on differences in symptomatology. When the experimental data are complete it is hoped that a preliminary classification of cacao viruses can be published.

Mechanical Transmission. (T. W. Tinsley)

Further attempts at mechanical transmission of swollen shoot virus have been made using very dilute extracts of leaves, as Fulton (*Phytopathology*, **42**, p. 413, 1952) found that rose-mosaic virus could be transmitted mechanically using dilute extracts, whereas undiluted juice was non-infectious. Cacao leaves from infected seedlings were ground in a large volume of pH7 phosphate buffer, with sodium sulphite present, and the extract was used for test inoculations on various plants. Among the plants tested cucumber and cowpea were used in several experiments. There was no evidence that virus had been transmitted.

Effect of Host Plant Nutrition. (A. L. Wharton and S. N. Adams)

The effect of the major nutrients—nitrogen (N), phosphorus (P) and potassium (K)—separately and in combination—on healthy and virus-infected cacao seedlings has been studied in water-culture experiments. The culture solutions used were those of Arnon (*Amer. J. Bot.*, **25**, p. 322, 1938) slightly modified. Healthy and infected Amelonado beans were germinated in washed sand and then transferred to Kilner jars containing the nutrient solutions, which were aerated three times daily and changed at three-weekly intervals. The jars were darkened to prevent algal growth.

Two preliminary experiments (I and II) were undertaken in 1953, but no results were obtained from the first as all the plants died. The results from Experiment II, which were briefly discussed in the thirty-second Quarterly Report, have been amplified by those from more recent experiments (III and IV). Two further experiments (V and VI) have been started.

Experiment III included eight treatments: NPK, PK, NK, NP, K, P, N and O (no nutrients), and ran for two months. Experiment IV compared the effect of N at four levels—half normal, normal,

twice normal and four times normal—each with normal levels of K and P. It continued for four and a half months. In both experiments there were five single-plant replicates of each treatment. Records of leaf symptoms resulting from nutritional deficiencies or excesses were made fortnightly throughout the experiments, on completion of which the plants were scored for root and stem swellings and the dry weights recorded.

Retarded growth due to infection was shown in both experiments. The greatest difference in dry weight was between healthy and infected plants receiving N. The growth of healthy and diseased plants in different culture solutions showed the same trends. In Experiment III, plants receiving complete NPK grew best, followed by those receiving NK, NP and N alone. Plants in solutions without N were poorly developed. In Experiment IV, the four-times-normal level of N proved toxic; growth with half normal was slightly retarded and that with twice normal extremely poor. As was previously noted in Experiment II, root swellings were fewer and less severe on plants receiving N, and there was a progressive reduction in their number from low to high levels of N in Experiment IV.

No treatment had any pronounced effect on the leaf symptoms of virus-infected plants, though statistical analyses on the ratios between number of leaves on a plant showing a particular symptom and its total leaves revealed small differences, which require further investigation. There was no apparent effect of virus infection on defoliation, the degree of which was only influenced by the nutrient treatments. Poor growth and severe defoliation in treatments lacking one or more major elements made the analysis of virus-symptom records difficult. For example, N appears to increase the expression of 'fern-leaf', but it is probable that this is simply a reflection of the number of leaves borne on the plants—treatments lacking in N do not produce sufficient leaves to allow the chronic 'fern-leaf' expression to develop.

These drawbacks were taken into account when designing Experiments V and VI. The plants in these experiments are receiving, in all treatments, at least the minimum requirement of all three major elements to keep them growing and reduce defoliation to a minimum. It is hoped to continue these two experiments for at least six months.

Experiment V is a repetition of III, but symptom recording is restricted to 'flush' and 'hardened flush' leaves. Additional records, such as the weights of the plants at regular intervals and chemical analyses, are also being kept. Experiment VI is a repetition of IV, using only three levels of N and restricting symptom recording to observations on root swellings. At the end of the experiment, it is hoped to study the effect of the nutrient treatments on availability of

the virus to vectors, and on the susceptibility of the uninfected control plants to infection.

Chemical Detection of Virus Infection. (E. M. Holden and G. Usher)

Work on this project has continued, based on the colour test described by Tinsley and Usher (*Nature, Lond.*, **174**, p. 87, 1954; *Ann. Rep. WACRI*, 1953-54, p. 12).

Extracts were made by macerating leaves with water or 0.1N HCl in a blender and squeezing through cotton cloth. Water extracts are dark green-brown in colour and from diseased leaves they are darker than those from healthy leaves made under the same conditions. Clarification by filtration through kieselguhr gives clear dark brown solutions. When extracts are heated with NaOH at a concentration of 0.5N, material precipitates out even from clarified solutions. The centrifuged solutions are then different in hue from the original extracts and those from healthy leaves are usually paler.

The colour given by extracts from mature, undamaged, healthy, Amelonado leaves when heated with alkali is variable: a green, green-brown or red-brown colour is produced. Extracts from leaves showing symptoms of swollen shoot infection invariably give a dark red or red-brown colour. Symptomless leaves from an infected tree usually give this reaction, which is referred to subsequently as a positive reaction. Healthy and infected leaves dried for storage still give their appropriate reactions. Comparison between extracts was made visually using a scoring method, and the absorption was sometimes measured at various wavelengths in the visible region with a Unicam Spectrophotometer.

Dilute acid extracts are green and when clarified give nearly colourless solutions. Those from diseased leaves when heated with alkali give dark red solutions, with little trace of brown colour, and healthy extracts also give red, but of a much lower intensity. It is clear, therefore, that the substance giving the red colour is present in healthy leaves as well as diseased, but is in lower concentration.

Clarified extracts of both healthy and diseased leaves give less colour than crude extracts when heated with NaOH, indicating that the substance giving the red colour is only partly soluble and is partly associated with the particulate matter.

Preliminary work had indicated that the high intensity of colour given in the test by diseased leaves was connected with a higher 'tannin' content than that found in healthy leaves. Tannin was determined by the method described by Duthie (*Analyst*, **63**, p. 27, 1938) slightly modified, on 40 per cent. acetone extracts from finely ground dried leaves and on water and acid extracts of fresh leaves. The aqueous acetone-soluble tannin content of mature healthy leaves showed wide variation, ranging from 0.8 to 4.0 per cent. of the dry

matter, and most frequently between 1.5 and 2.0 per cent; diseased leaves had 4.4 to 10.7 per cent. The tannin content of water and acid extracts was also variable and those having a high concentration had a high colour intensity in the test. However, the intensity of colour is not strictly proportional to the total tannin present: crude extracts have a higher intensity of colour per unit weight of tannin than clarified extracts. Similarly, extracts from diseased leaves have a higher intensity per unit weight of tannin than extracts from healthy leaves. Acid extracts have a higher tannin content than water extracts of the same material.

High colour-test values which were obtained with supposedly healthy trees amongst the 'Trinidad Introductions' are being more fully investigated. All trees of the following selections have been tested: T60, T63, T65, T72, T73, T76, T79, T82, T85 and T87. Five samples were taken from each tree and tested both individually and when bulked together. In tests so far completed about 20 per cent. of the trees have given a high intensity of red colour for the bulk sample. Individual samples from each tree have given considerable variation in colour. Tannin determinations indicate that a high colour-test value is given by extracts with a high tannin concentration.

Flush leaves of healthy trees have a very high tannin content (up to 20 per cent. of the dry matter) and give a high colour-test value. Acid extracts are deep pink in colour but this changes to green on addition of alkali, and on boiling to dark red. The pink pigment of acid extracts can be extracted into amyl alcohol to give a pink layer. The colour-test red pigment changes to yellow in acid solution, from which it is extracted by amyl alcohol to give a yellow layer.

Curves have been plotted of the amount of light absorbed between 400 and 700 $m\mu$ by acid extracts of leaves after heating with alkali. The shape of the curve was the same for diseased and healthy extracts of mature leaves, there being high absorption at 400 $m\mu$ falling sharply to 460 $m\mu$, a pronounced shoulder in the 500 $m\mu$ region and then a steep fall. Flush leaves give a similar curve but with a small peak at 500 $m\mu$.

Plants with a high tannin content, such as *Mangifera indica* L., *Caesalpinia* sp., *Casuarina* sp. and *Rosa* sp., have a high colour-test value, which gives further support to the view that the reaction is associated with the tannin fraction.

Work has started on the separation by paper partition chromatography of some of the individual polyphenol components of the tannin fraction. This is with the object of identifying the substance responsible for the colour-test and studying the changes in some of the polyphenols caused by infection with swollen shoot virus.

In an experiment using the New Juaben strain transmitted to young Amelonado seedlings by infective mealybugs (*Pseudococcus njalensis*), the first positive colour-test reaction was obtained after ten days and the first symptoms ten days later. On the first plant to give a positive reaction symptoms appeared twenty-four days after infestation with mealybugs. When six-month-old plants were infected with the Bosumtwe strain by grafting, the first positive reaction to the chemical test was obtained after nine days, but virus was not recovered by back-testing with *P. njalensis* until six weeks after grafting.

Amelonado seedlings infected with the following strains from the WACRI collection all gave positive reactions in each of five tests: New Juaben, Bisa, Bosumtwe, Bosumuoso 2, Mampong, Kpeve, Offa Igbo, Alaparun, Ilesha and Yakasse. Two mature trees naturally infected by the Peki strain also gave a positive reaction.

Every tree in eighteen quarter-acre blocks of Amelonado trees on the Old Station was tested; just over 1,500 (almost a third of the total) gave a positive reaction. These most commonly occurred around visually detected virus outbreaks, and the remainder in small groups or singly. While this distribution tends to suggest that the symptomless trees which gave a positive reaction may be virus-infected, it is difficult to believe this because of their number; moreover, during the six- to ten-month period since testing less than 2 per cent. have developed symptoms. As a check, material from a random selection of these trees has been grafted to test seedlings, but conclusive results are not yet available.

Samples of symptomless leaves from sixty-two symptom-bearing trees were tested, and all gave a positive reaction. Sixteen trees showing symptoms were each sampled at from ten to forty sites (depending on the size of the tree), and grafts were made to test plants from five sites chosen at random on each tree. All the trees gave a positive reaction to the colour-test when samples were bulked, but 23 per cent. of the individual samples gave negative results, which might suggest that the virus is not completely systemic in the aerial parts of the tree. This is supported by the fact that grafts taken from infected trees do not always produce infection in the test plants, even when satisfactory union has occurred.

Other methods for the detection of virus infection have also been investigated. Those of Ninomiya and Hino (*Bull. Fac. Agric. Yamaguti Univ.*, **2**, p. 13, 1951), Lindner (*Science*, **107**, p. 17, 1948), and Lindner, Kirkpatrick and Weeks (*Science*, **112**, p. 119, 1950), depend on a colour reaction which develops on treating leaf discs or whole leaves with alkali. These three methods are unreliable for the diagnosis of virus in either mature cacao trees or young seedlings. In preliminary trials, a technique described by Cornuet (*C.R. Soc. Biol. Paris*, **237**,

p. 1364, 1953) for the diagnosis of potato leaf-roll virus in potato tubers gave promising results when applied to aqueous extracts of mature Amelonado cacao leaves, those from infected trees giving a positive reaction even when symptomless. This method depends on the conversion of glutamine to ammonium glutamate by heating an alcoholic extract, buffered at pH7, in a boiling water-bath, and estimating the ammonium radical with Nessler's reagent.

Conclusions.

Like most other tests devised for the chemical detection of plant viruses, the Tinsley-Usher colour-test is unsuitable for large-scale field application. Provided that a suitable sampling technique is employed, there seems little chance of an infected tree failing to give a positive reaction; but not all trees which do so are virus-infected. Not only do certain cacao types other than West African Amelonado give a red-brown colour when known to be virus-free, but it seems likely that Amelonado does the same under certain circumstances.

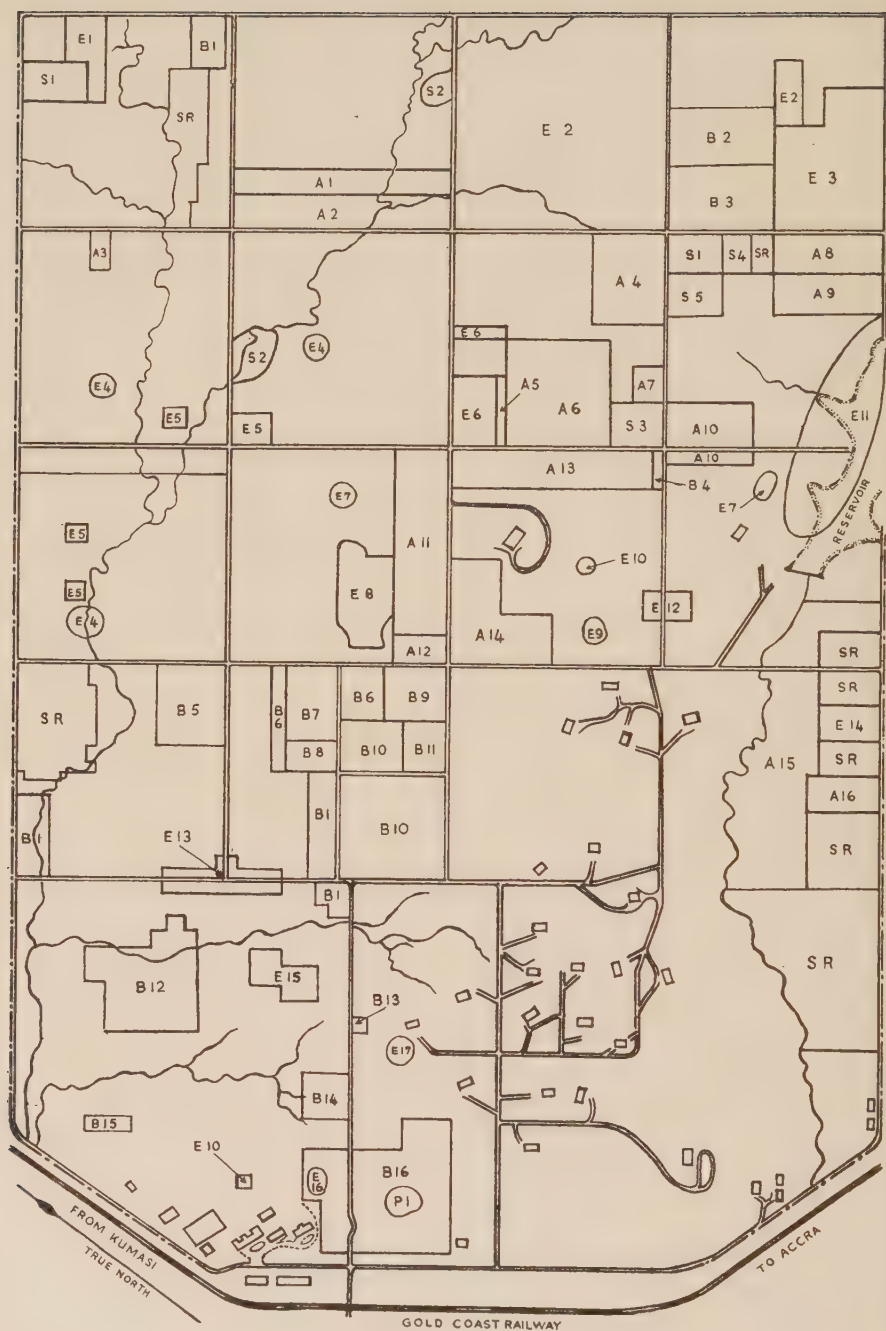
Leaves with necrotic lesions taken from virus-free trees tend to give a high colour-test value and it is possible that nutrient deficiencies, attacks by pathogens or even a high light intensity may have the same effect. The red colour which denotes a positive reaction in the colour test clearly seems to be associated with a high concentration of a component of the tannin fraction, and there is no obvious reason why virus infection alone should increase this. Continuation of work on the chemical aspects of the test is justified by the information it may provide on the biochemistry of virus infection.

Morbid Histology of Virus-Infected Cacao. (T. W. Tinsley)

This study has now been completed and a full account is to be published soon. The main point which has been established is that symptoms in the mature leaf result from the failure of young virus-infected tissues to differentiate, so that some juvenile characters persist. Transverse sections of infected leaves, under high magnification, revealed an absence of spaces in the spongy mesophyll of chlorotic areas.

Resistance and Tolerance. (W. T. Dale)

In earlier tests at WACRI certain Upper Amazon cacao material, particularly that of Nanay parentage, showed some resistance to infection with the New Juaben strain, this resistance being associated with tolerance (Posnette and Todd, *Ann. appl. Biol.*, **38**, p. 785, 1951). During recent studies on virus multiplication, in which several Upper Amazon types were used, it was noticed that the Iquitos type was difficult to infect. Consequently, pods of Iquitos parentage derived from hand-pollinations have been supplied by the Plant Breeders for testing.



Experimental Areas, Tafo Station

EXPERIMENTAL AREAS, TAFO STATION

A—Agronomic Investigations

- A 1—Upper Amazon Seed Multiplication Plot.
- A 2—Upper Amazon Spacing and Pruning Experiment.
- A 3—Frequency of Harvesting Experiment.
- A 4—Transplanting Demonstration.
- A 5—*Herrania* Plot.
- A 6—Uniformity Trial with Young Amelonado Cacao.
- A 7—Amelonado Source Experiment.
- A 8—Transplanting Experiment IV—Effect of Age and Reduction of Foliage.
- A 9—Transplanting Experiment V—Effect of Age and Road Transport.
- A10—Establishment Experiment II—Comparison of Planted and Natural Shade.
- A11—Amelonado Spacing Experiment.
- A12—Pruning of Fan Cuttings Experiment.
- A13—Establishment Experiment I—Types of Planting Material, Holing and Mulching.
- A14—Seedlings *versus* Rooted Cuttings Experiment.
- A15—*Herrania* Bulking Area.
- A16—Transplanting Experiments I and II—Superphosphate and Reduction of Foliage.

B—Botanical Investigations

- B 1—Clonal Collection.
- B 2—Clonal Trial III—to be planted in 1956.
- B 3—Progeny Trial IX—1954.
- B 4—Training of Fan Cuttings Observation Plot.
- B 5—Clonal Trial I—Gold Coast Selections.
- B 6—Cytogenetics Observation Plot.
- B 7—Progeny Trial VIII—1952.
- B 8—Albino Plot.
- B 9—Clonal Trial II—Gold Coast Selections.
- B10—Trinidad Introductions Area.
- B11—*Theobroma* and *Herrania* Species Area.
- B12—Progeny Trial II—1942.
- B13—Progeny Trial VI—1943.
- B14—Capsid Resistance Variety Trial.

- B15—Progeny Trial IV—1941-44
- B16—Progeny Trial I—1940.

E—Entomological Investigations

- E 1—Capsid Attack in Light and Shade.
- E 2—Mealybug Aerial Dispersal and Population Studies.
- E 3—Insecticide Trials Area.
- E 4—Seedling Traps for Seasonal Abundance of Mealybugs.
- E 5—Radio-active Mealybug Release Areas.
- E 6—Ant and Mealybug Establishment Experiment.
- E 7—Systematic Insecticides Trial Area.
- E 8—Capsid Ecological Study Plot.
- E 9—Studies of Mealybug Movement in the Canopy.
- E10—Light Traps for Capsids.
- E11—Mealybug Aerial Dispersal Studies.
- E12—Capsid Pocket Regeneration Demonstration Area.
- E13—Mealybug Movement Roadside Experiment.
- E14—Capsid Control Experiment—Dusting and Pruning of Seedling Cacao.
- E15—Capsid Control Costing Trial—Dusting and Pruning Method.
- E16—Light Trap for Ants and Mealybugs.
- E17—Effect of Forest Trees on Mealybug Deposition and Establishment.

S—Soil Fertility Investigations

- S1—NPK Experiment on Young Seedling Cacao.
- S2—Types of Phosphate Experiment on Bearing Cacao.
- S3—Mineral and Organic Manures Experiment on Coppiced Cacao.
- S4—Effect of Forest Litter Experiment on Young Seedling Cacao.
- S5—Establishment Experiment IV—Mineral Fertilizers, Mulch, and Irrigation.

P—Pathological Investigations

- P1—Black Pod Spore-Trapping Experiment.

S.R.—Seedling Reserve.

Two methods of testing have been used. In the first method, every bean from each pod was dissected (Posnette, *Nature, Lond.*, **159**, p. 500, 1947) and colonised for one day with forty infective crawlers (first- and second-instar nymphs) of *Pseudococcus njalensis*, prior to planting. Similarly treated Amelonado beans were planted along with each batch of Iquitos beans, as controls. All plants which failed to develop symptoms were subjected to back-transmission tests at four months old. Each plant to be back-tested was infested for two to three days with virus-free crawlers and gravid females of *P. njalensis* that had fasted for two days, and crawlers were then transferred to five test beans at the rate of thirty per bean.

Symptoms in the Iquitos seedlings differed in intensity, but were almost invariably much milder and often later in appearance than those of the Amelonado controls. There was usually little effect on growth at this stage; leaf symptoms were sometimes faint or evanescent and, as the back-tests revealed, were occasionally absent; swellings were rare. Besides being more tolerant, some of the Iquitos progenies seemed to be more resistant to infection, at least as dissected beans, than Amelonado. An alternative, though less likely explanation of the results is that some symptomless plants were infected, but contained too little available virus to be detectable by back-transmission tests. The percentages of plants amongst the various progenies and their controls which gave no evidence of infection within seven months of infestation with infective mealybugs were as follows:

T17/1131 × 1220—(59);	T17/1070 × 447—(49);
T17/1131 × 1159—(46);	T17/1131 × 1157—39;
T17/1072 × 433—23;	T17/1072 × 358—21;
T17/1070 × 1219—13;	T17/1072 × 357—0;
controls (total)—10.	

The brackets around certain percentages indicate trials in which some control plants failed to become infected, which should not have occurred with forty crawlers per bean; so these high figures may not be as satisfactory as would appear.

At seven months old, each apparently uninfected plant was colonised for one day with 200 infective crawlers. Complete results are not yet available, but it is already apparent that few plants will escape infection.

In the second testing method, which superseded the first, all the beans from each pod were planted intact in boxes of sand, along with Amelonado controls. The resulting seedlings were then 'twinned', as described by Posnette (*Trop. Agric., Trin.*, **19**, p. 146, 1942), and replanted singly in baskets. Provided both 'twins' received a fair share of root and hypocotyl, and replanting was done immediately after separation, there were few casualties. At about three months old, one

plant of each pair (the survivor where one had died) was infested for one day with 150 infective crawlers of *P. njalensis*. It is intended to back-test and subsequently to re-infest with infective crawlers, where necessary, all apparently virus-free plants.

This second method of testing has several advantages, outweighing the convenience of dissected beans as test plants. The ease with which beans can be infected compared with normal plants, particularly older ones, suggests that their use could cause resistance due to some external character (say a thick cuticle impeding vector penetration) to be overlooked; though the evidence of resistance in Iquitos beans suggests that it is at least partially chemical in nature. 'Twin' plants are particularly suitable for comparing the growth of infected and virus-free plants; more important, their use ensures that virus-free material of promising lines will be readily available for further testing. So far, it is not clear if seedlings derived from the same pod show segregation for resistance; the proportions failing to become infected after testing may reflect either a common low level of resistance or a mixture of relatively resistant and susceptible types. By producing a number of clonal plants from each uninfested 'twin' and carrying out appropriate infection tests with vectors, it should be possible to elucidate this important point.

It should be stressed that even if these studies lead to the production of sufficiently resistant plants, a number of years must elapse before their performance in the field can be assessed. Moreover, there is no guarantee that types developed for resistance to the New Juaben virus (certainly the most important in the Gold Coast) would be resistant to other cacao viruses. Tolerance to the New Juaben virus certainly occurs in young plants of certain Upper Amazon types, and it may persist as they mature. It is not considered a desirable feature unless proved to be associated with a high degree of resistance to infection and/or a very low availability of virus to vectors. In the absence of these characters, tolerant trees are liable to become permanent and not readily detectable reservoirs of virus menacing more susceptible cacao.

MEALYBUG STUDIES

Movement in and between Trees. (P. B. Cornwell)

Experiments are in progress to study mealybug movement on cacao trees supporting high populations. The pattern of movement is being elucidated by the attachment of bait, in the form of fresh cacao twigs, at different elevations from ground level to the tips of the canopy branches. The use of such bait on dead trees provides an indication of the number of insects carried by wind. Results obtained so far show

that the first instar nymphs are the most actively moving stage (90 per cent.) and that movement is most marked on the canopy branches.

Further attempts have been made to obtain radio-active trees for the production in the field of labelled mealybug populations. Radio-active populations have been obtained but the use of this technique on a field scale is handicapped by inefficient translocation and distribution of 'tracer' within the tree. Preparations have been made for the release of large radioactive mealybug populations from radio-active seedlings tied to the branches of release trees.

Effect of Wind Currents. (P. B. Cornwell)

It has already been shown that mealybugs are carried by wind. The study of this type of dispersal is of practical importance in connection with the spread of the swollen shoot virus and is of particular interest in connection with discontinuous or 'jump spread' of the disease. Investigations have been made to determine the distance of movement and the conditions under which it occurs. Various experiments are in progress in which mealybugs are caught on adhesive traps and cacao seedlings; preparations are being made for the use of suction traps to provide more detailed estimates of the density of mealybugs in the air.

An experiment was started in September 1954 to study the aerial movement of mealybugs at eight sites within an area typical of farmers' cacao. Mealybugs are caught on adhesive traps at various elevations from two feet above the ground to levels above the cacao canopy. The sites were selected to compare the effects of closed and open canopy on the numbers of vectors and their distribution at the different levels. Results obtained so far have shown marked differences in the numbers caught at the eight sites; eighty mealybugs have been recorded and more than half of these were taken at one site. It is considered that such differences may be related to the proximity of the traps to trees of exceptionally high mealybug density. In the presence of a closed canopy more mealybugs have been recorded at two and ten feet above the ground than at levels in and above the canopy; in the presence of an open canopy more insects have been recorded at the canopy level. The factors responsible for these differences in distribution are at present obscure.

To examine more critically the relationship between catches and the proximity of traps to trees of varying mealybug density, an experiment is in progress in which 100 traps are distributed over an area of 10,000 square feet of cacao with a closed canopy. The traps are suspended at six feet above ground on a grid of wires which do not interfere with air movement. Catches on these traps are being compared with the numbers caught in a similar area from which all cacao has been removed but where forest trees remain standing. It is not

possible to draw conclusions from the limited number of results so far obtained.

There have been numerous reports suggesting that more swollen shoot disease outbreaks occur along roadsides and footpaths than in less exposed areas. Two theories have been advanced to account for this: (1) that roads and footpaths provide conditions conducive to air movement and the subsequent dissemination of vectors, and (2) that the number of outbreaks may be related to the number of observers, who are more numerous along roads and paths. An experiment was started in December 1954 to investigate the aerial movement of vectors along a bush road which carries a considerable amount of motor traffic. Adhesive traps were set up along the side of the road and at a number of positions in the cacao bordering the road. A total of sixty mealybugs has so far been recorded and at present there is no evidence to support the theory of greater vector dissemination along roads and paths.

In a preliminary experiment to investigate the aerial movement of vectors to seedlings at various distances from cacao a total of forty-five mealybugs was recorded. The traps which were set up on the WACRI reservoir were very exposed in position and complete insulation from ants was provided. Identification of the insects showed that more than half were *Planococcus citri* with a single representative of *P. njalensis*. This experiment was repeated in August 1954 using seedlings at distances not exceeding 200 yards from the nearest cacao and about 150 mealybugs have so far been recorded. A large percentage of these belongs to the *P. citri/kenyae* group. It was originally believed that the abundance of the various species was related to the greater ability of some species to be carried by wind. Recent studies, however, have suggested that all species are probably equally dispersed but the degree of exposure of the traps influences the establishment of the various species. At present no relationship has been shown between the size of the catch and the distance of the traps from the nearest cacao.

An experiment was carried out during the dry season to study the effect of a single large *Ceiba pentandra* on the deposition and establishment of mealybugs on seedlings growing in baskets beneath and around the tree. Ninety-six traps were used and insulated from ants with banding grease. Larger infestations were recorded in the area which received the most shade. The experiment was repeated and similar results were obtained. There is no marked prevailing wind in the area and it is believed that the positions of infestation are related to conditions of establishment. All the mealybugs recorded belong to the *P. citri/kenyae* group and no representative of *P. njalensis* has been found.

In addition to the various factors being investigated in the studies described above, continuous trapping and recording have provided an indication of the seasonal abundance of airborne vectors. Catches from both the adhesive and seedling traps have shown marked increases during the dry season, falling off with the early rains.

Seasonal Fluctuations. (P. B. Cornwell)

A study of the seasonal variation of mealybug populations in two different types of habitat has been completed. A comparison of the populations on cacao growing in dense secondary bush and under well-cultivated conditions has shown that cultural practice produces no marked effect on the rate of mealybug infestation or population size. A range of very low and very high populations is found under the two conditions. Populations of *Crematogasterine* ants are slightly but significantly higher in bush and a closer correlation between the ant and vector populations exists. *Pheidoline* ants are more abundant under cultivated conditions but there is no apparent correlation between their numbers and the size of the mealybug population. Previous work has shown no marked seasonal trends in mealybug populations. Fortnightly sampling over a period of thirteen months has shown increases in population during the wet seasons particularly during the main rains of October and November. From a preliminary analysis of the data it appears that a rise in population results from an increase in the number of colonies and not from an increase in size of individual colonies. Population trends of ants, predators and parasites have been elucidated. Full details of the survey will shortly be published.

Ant-Mealybug Relations. (P. B. Cornwell)

In collaboration with the Soil Scientist a study is being made of the tent-building habit of *Crematogasterine* ants on 2,000 heavily infested cacao seedlings originally laid down as a fertilizer trial. Seasonal trends in the numbers of ant tents are being recorded together with the effect of the removal of shade. A further experiment is in progress to study the effect of shade and no-shade treatments on the establishment on cacao trees of *Crematogasterine* ants and mealybugs which are artificially colonised and those which are air-borne.

Three light traps were set up at the beginning of the year to study the conditions which influence the emergence of winged ants and to investigate whether ants carry mealybugs during mating flights. During the last three months the mouths of over 57,000 ants were examined but no mealybugs were found. One mealybug was found attached to the wing of a specimen of *Crematogaster luctans* but it is extremely doubtful if the insect was actually carried in this manner or even by this species.

Biological Control of Mealybugs. (F. E. Decker)

Shipments of parasites from the Commonwealth Bureau of Biological Control during the year have consisted only of *Anagyrus Pseudococci* and *Acroaspidia myrmicoides*. The former has been reared on *Pseudococcus longispinus* in addition to the host species recorded in last year's report. *Acroaspidia myrmicoides* has also reproduced in *Pseudococcus njalensis*, *Ferrisia virgata* and *Phenacoccus madeiriensis*.

As mentioned in the previous Annual Report, releases in the areas outside Tafo have been discontinued. During the year all further liberations have been made in the Institute's Old Station at Tafo.

In all 289,893 parasites comprising the following species have been released:

<i>Anagyrus pseudococci</i> Gir.	..	..	16,000
<i>Blepyrus saccharicola</i> Gahan	..	..	675
<i>Chalcaspis phenacocci</i> Ashmead	..	..	78
<i>Leptmoastix dactylopii</i> How.	..	..	370
<i>Pseudaphycus angelicus</i> How.	..	..	168,665
<i>Pseudaphycus mundus</i> Gahan	..	..	104,105

Following the discontinuation of releases in the out-station areas, intensive collections of mealybugs have been carried out during which a total of 24,546 *Pseudococcus njalensis* have been taken. From these 522 indigenous parasites and two specimens of *Pseudaphycus angelicus* have emerged, the latter from collections made at Bunso and Koransang. Two earlier recoveries of this introduced parasite were made at Koransang in 1951.

Although no exotic parasites have been recovered from mealybugs collected from the Old Station, it is of interest to note that *Pseudaphycus angelicus* has been reared on three occasions from mealybugs collected from the Square Mile in connection with investigations into the dispersal and behaviour of mealybugs. These occurred after the routine releases had been made at Tafo. It appears reasonably certain that these and the other recoveries represent a successful establishment of *P. angelicus* under Gold Coast conditions.

As a result of a decision to re-introduce ladybird beetles, supplies of *Scymnus sordidus*, a Coccinellid predator of Pseudococcidae have been arriving from California since February 1955. This beetle has been reared successfully on *Pseudococcus njalensis*, *Pseudococcus brevipes* and *Ferrisia virgata*, and its release on the Old Station at Tafo has already been commenced.

BLACK POD DISEASE

Spraying and Harvesting Trials. (A. L. Wharton)

Application of first-year spraying treatments on the two field-control trials at Bunso Plantation has been completed. Following the

procedure in the Quarterly Reports for the past year, the experiments will be referred to as Trials I and II.

Trial I. This experiment has $3 \times 3 \times 2 \times 4$ split-plot factorial design with two replicates. Three fungicidal sprays, Perenox, Bordeaux Mixture made with calcium carbide and Bordeaux Mixture made with lime, have been applied at three frequencies during the first year: monthly, bi-monthly and no application. Combined with these treatments are weekly (frequent) and monthly (infrequent) harvesting. The split-plot design was adopted to allow four 'second-phase' frequencies of spraying to be introduced in subsequent years. Forty-eight trees comprised a main plot, giving a total of 1,728 trees for the whole experiment, and the two replicates are separate blocks of high yielding Amelonado cacao, growing on similar alluvial soil types on either side of the Birim River. According to Department of Agriculture records, both areas have been subject to very heavy losses due to black pod disease.

The trial was laid out in July 1953 and, during the 1953/54 season, weekly and monthly harvesting treatments were applied; spray applications began in May 1954.

TABLE 6
Trial I, Season 1953/54
Mean Numbers of Pods and Wet Weights of Beans per Tree

Category	Harvesting Treatments			
	Weekly	Monthly	Weekly	Monthly
	Number per tree	Percentage of total	Number per tree	Percentage of total
Total pods	38.54	57.9*	28.00	42.1*
Undamaged	14.28	37.1	7.13	25.5
Black pods	12.81	33.2	9.91	35.4
Damaged otherwise ..	11.45	29.7	10.96	39.2
Rodent-damaged pods ..	7.55	19.6	7.55	27.0
Total pods discarded ..	15.31	39.7	13.54	48.4
Black pods discarded ..	7.12	18.5	5.75	20.6

	lb. per tree	Percentage of total weight	lb. per tree	Percentage of total weight
Total weight of beans ..	4.7	66.6*	2.4	33.4*
Weight of beans from undamaged pods ..	3.5	74.8	1.7	71.1
Weight of beans from black pods	0.61	12.9	0.31	13.1
Weight of beans from other damaged pods ..	0.58	12.3	0.38	15.9

*Based on combined weekly and monthly totals.

Table 6 gives the mean numbers of pods of various categories per tree, and corresponding weights of good wet beans. There was a

marked difference in total pods from weekly and monthly harvested plots, and both replicates (which were recorded by different people) showed the same effect, although the reason for the difference is obscure. There was no appreciable difference in total yield of pods between the two blocks and, as the treatments were assigned to the plots at random, it seems unlikely that the difference arose through better-yielding plots being awarded to the weekly harvesting treatment. The same difference occurred in Trial I during the 1954/55 crop season (see below), and although not shown by the overall results from Trial II, it was again apparent in three of the four replicates. Two 'Frequency of Harvesting' trials carried out by the Division of Agronomy during 1954/55, and described elsewhere in this Report, showed the same effect: there was an increasing yield of pods per tree as the period between successive pickings decreased. On the basis of the Bunso results, and assuming that a partially diseased, immature pod continues to absorb nutrients from the tree for some time, it could be postulated that the frequent removal of such pods enables the tree to set more fruit; but the low incidence of disease in the Frequency of Harvesting trials suggests that this is not the explanation.

The difference in total wet weight of beans between weekly and monthly treatments in Trial I was much greater than the corresponding difference in total pods. This is associated with a highly significant difference in the percentages of undamaged pods, largely attributable to differences in the incidence of rodent damage between the two treatments. A linear relationship was established between the number of pods borne on a tree and the number attacked by rodents. The rate of increase in the number of pods attacked by rodents with increasing total number of pods per tree was greater for monthly than for weekly harvesting. It appears that the frequent removal of ripe pods, as opposed to leaving many of them liable to rodent attack for up to a month, has reduced losses due to these pests. Despite the difference in total pods, virtually the same number of pods was attacked by rodents in the two treatments—6,521 on weekly and 6,522 on monthly harvested plots. These figures include pods attacked superficially by rodents as well as the more obvious ones with beans gnawed or removed. Close examination of many pods with wound fungi, such as *Trachysphaera fructigena* Tabor and Bunting, showed that the original points of fungal entry were small wounds caused by rodents, to which the loss of such pods should therefore be attributed. Clearly many more pods are spoiled by these pests than was previously realised, and it is probable that in the past much of the superficial damage caused by them has been overlooked and the resulting loss attributed to black pod disease.

In this first year, weekly harvesting had no significant effect on the incidence of black pod disease, the percentage of black pods discarded, or the wet weight of beans recovered from partially usable black pods, although in each instance the figures for weekly harvested plots were slightly lower than those for monthly harvested ones. Between them, black pod disease and rodents were responsible for 84 per cent. of all pods damaged and 96 per cent. of all those completely discarded.

Season 1954/55. Table 7 compares frequent and infrequent harvesting for the current year, during which the sprays were applied. Unlike those for the previous year, the figures cover a complete season; hence there are increased average numbers of pods per tree. The difference in total pods between the two treatments is still apparent, the percentages being virtually the same as in 1953/54. Increased numbers of undamaged pods were harvested for both treatments, especially weekly harvesting. During this year weekly harvesting has had a significant effect ($P=0.05$) on the incidence of black pod disease, though this only represents a difference of 6 per cent. between the treatments. There was also a greater difference in number of discarded black pods. The figures for rodent-damaged pods are quite different from those of the previous year. They have not yet been analysed, so it is not known if spraying has had the effect of making pod husks unpalatable to the pests.

TABLE 7
Trial I, Season 1954-55
Mean Numbers of Pods and Wet Weights of Beans per Tree

Category	Harvesting Treatments			
	Weekly		Monthly	
	Number per tree	Percentage of total	Number per tree	Percentage of total
Total pods	52.7	57.7*	38.6	42.3*
Undamaged	28.1	52.3	18.1	46.4
Black pods	12.1	23.0	11.5	29.9
Damaged otherwise ..	12.5	24.7	9.0	23.7
Rodent-damaged pods ..	9.2	17.5	6.4	16.6
Total pods discarded ..	19.8	37.7	17.8	46.1
Black pods discarded ..	9.0	17.1	9.6	24.9

	lb. per tree	Percentage of total weight	lb. per tree	Percentage of total weight
Total weight of beans ..	7.53	62.2*	4.57	37.8*
Weight of beans from undamaged pods ..	6.50	86.3	4.00	87.5
Weight of beans from black pods	0.67	8.9	0.37	8.1
Weight of beans from other damaged pods ..	0.36	4.8	0.20	4.4

*Based on combined weekly and monthly totals.

None of the spraying treatments affected the incidence of damage to the pods from various causes, including attack by black pod disease. Black pod infections have been classified into three types: pods infected at the proximal end, pods infected distally and those completely blackened so that the original point of infection could not be ascertained. Table 8 gives the distal infections, expressed as a percentage of the proximal and distal combined (excluding figures for pods with an unknown point of infection). It shows effects of sprays and frequencies of spraying on distal black pod infection, carbide-Bordeaux mixture applied at monthly intervals being the most effective treatment.

TABLE 8
*Distal Black pod Infections as a percentage of
Distal and Proximal Infections*

	<i>No spray</i>	<i>Bordeaux mixture</i>	<i>Perenox</i>	<i>Carbide-Bordeaux mixture</i>
Bi-monthly application ..	50.6	42.7	42.1	35.4
Monthly application ..		33.8	39.0	29.2

TABLE 9
*Numbers of Distal (D) and Proximal (P) Infections
as percentages of total pods*

	<i>No spray</i>		<i>Bordeaux mixture</i>		<i>Perenox</i>		<i>Carbide-Bordeaux mixture</i>	
	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>
Bi-monthly application ..			5.09	7.07	4.71	7.36	3.77	7.40
	6.44	7.56						
Monthly application ..			3.87	7.35	5.67	10.12	3.73	8.44

Table 9 compares the effects of the treatments on the numbers of proximal and distal infections, expressed as percentages of the total pods (excluding black pods with an unknown point of infection). No treatment materially affected the amount of proximal infection which was, in fact, higher for two of the spraying treatments than for the unsprayed plots. These results suggest that most proximal black pod infections originate from mycelium of *Phytophthora palmivora* Butl. in the cushions (*vide infra*, 'Cushion infection'), in which event sprays applied to the pod surface cannot be expected to have any direct effect on a high proportion of pod losses due to the disease. They might, though, have an indirect effect if continued for a few years (particularly if combined with frequent removal of infected pods) by reducing the infection of cushions. Experiments are planned to try to

find out how much proximal-end infection on this trial does arise from diseased cushions and how much is due, like the distal infections, to air- or splash-borne spores.

Trial II. This was designed as a $3 \times 2 \times 2$ randomised block experiment with four replicates. Three spraying treatments—Perenox, Blitox and nil (control)—were included, applications being made at fortnightly and monthly intervals. Weekly and monthly harvesting treatments were incorporated. Twelve-tree plots were used, giving a total of 576 trees in the whole experiment. Perenox was included in this trial to act as a standard fungicide, affording some comparison with Trial I. No pre-treatment records were taken; both harvesting and spraying treatments began in May 1954. The area of cacao used for this trial is not as uniform as for Trial I, and during the current year there were considerable differences in the yield between the replicates, varying from about twenty-four to forty pods per tree.

TABLE 10

Trial II, Season 1954-55

Mean Numbers of Pods and Wet Weights of Beans per Tree

Category	Harvesting Treatments			
	Weekly		Monthly	
	Number per tree	Percentage of total	Number per tree	Percentage of total
Total pods	32.6	50.8*	31.5	49.2*
Undamaged	21.3	65.3	18.9	59.9
Black pods	6.5	19.9	7.2	23.0
Damaged otherwise ..	4.8	14.8	5.4	17.1
Rodent-damaged pods ..	4.1	12.7	4.0	12.7
Total pods discarded ..	8.5	26.1	11.2	35.4
Black pods discarded ..	3.6	11.0	6.0	19.0

	lb. per tree	Percentage of total weight	lb. per tree	Percentage of total weight
Total weight of beans ..	5.4	55.7*	4.3	44.3*
Weight of beans from undamaged pods ..	4.8	88.9	3.9	90.7
Weight of beans from black pods	0.34	6.3	0.26	6.0
Weight of beans from other damaged pods ..	0.26	4.8	0.14	3.2

* Based on combined weekly and monthly totals.

A comparison of weekly and monthly harvesting treatments is given in Table 10. The general picture is the same as for the 1954/55 results from Trial I, except that there is a lower incidence of disease and pest damage, resulting in a higher percentage of undamaged pods. There is only a slight reduction in the incidence of black pod disease due to weekly harvesting, but there is a greater effect on the number of black pods discarded as completely useless, and on the recovery of good wet beans from partially damaged black pods.

The effects of spraying on the main categories of pods have not yet been completely analysed statistically, but it is again apparent that the sprays have not appreciably affected the incidence of black pod disease. It may not be possible to get as complete an estimate of the effects of spraying on distal and proximal black pod infections as was obtained from Trial I; figures available for the two types of infection are very low, due to the lower general incidence of the disease and the smaller size of the experiment.

Frequency of picking experiments. (R. Wickens)

It is noted above that the total number of pods produced by cacao trees which were harvested weekly was greater than that from those harvested monthly. Two experiments designed to examine this effect rather more critically were carried out during the past crop-year. Four frequencies of harvesting, namely three-, six-, twelve- and twenty-four day intervals were tested in randomised block experiments at Tafo and on one of the Institute's substation farms at Kukua. The difference in age of the trees at the two sites suggested that there would be a low incidence at Kukua and high at Tafo: at Kukua nine years old and at Tafo twenty-five to thirty years old. The proportion of pods discarded at both places was uniformly low and of the order of 7 per cent. of total pods picked. Table 11 shows the result of these experiments expressed as good pods per tree.

TABLE 11
*Pods per tree resulting from varying
frequencies of picking**

Site	Frequency			
	3-day	6-day	12-day	24-day
Tafo.. ..	7.90	6.66	5.48	3.64
Kukua ..	8.23	9.58	6.75	6.22

* Detransformed square root values.

The effect of frequent picking is well marked at Tafo where it reaches a high level of significance and it is significant at Kukua, though less well marked. It is possible that the higher yield of the six-day frequency at Kukua over the three-day frequency may be related to the tree density, which is an important factor (*vide infra*—‘Spacing Trials’) in determining yield per tree.

Tree density at the sites of this experiment was not examined, but its possible influence on the results will be considered when the work is repeated. Whether or not such an effect is significant, the results show clearly that long intervals between pickings reduce the yield of good pods and, since the number of discards was small and much the same for all treatments, of the total pods.

Spore dispersal. (A. L. Wharton)

An experiment to investigate the airborne spread of spores of *Phytophthora palmivora* was started in August and terminated in December. A suction-type spore-trap was operated in the middle of the first Progeny Trial Area, at different levels above and below the cacao canopy, for a twenty-four-hour period during each week, the slides being changed every eight hours. The trap was situated at the centre of a circular block of eighty-nine trees in which all pods were artificially inoculated with the causal fungus on reaching a length of about 4 in., to build up a concentration of the disease. To increase the supply of spores still further, all pods harvested from the first P.T.A. were collected and broken within this central block. A further 176 trees, selected at random from the rest of the first P.T.A., were harvested weekly and pod-disease records were kept for each, in an attempt to measure any spread of the disease from the central source of high infection. No *Phytophthora* spores were caught by the trap, and the individual-tree records proved inconclusive. Most black pods were recorded on trees which lay in the paths of two wind currents on the leeward side of the centre. The black pods on these trees were only 5.5 per cent. of the total and it was not possible to trace any gradients of infection.

Cushion infection. (A. L. Wharton)

It was intended to use the 1,000 cushions labelled and recorded in 1953 (*Ann. Rep. WACRI* 1953-54) for cushion-infection experiments during the 1954/55 season. However, it became apparent early in the year that most of them were not coming into bearing, and only fifty-five have produced cherelles or pods so far. The last crop was, in fact, borne on cushions which had not yielded pods in the previous season. The classification of pods borne on labelled cushions was therefore continued during 1954/55; of the forty that gave one or more healthy, ripe pods in 1953/54, twenty-one did so again and the rest gave one or more wilted cherelles; of the fifteen giving one or more wilted cherelles in 1953/54, four did the same this year and the rest gave one or more healthy pods. Many of the cushions are now flowering and it appears that they may produce a better crop in the coming season.

Records of seasonal fluctuation in the number of black pods with infection at the proximal end, and therefore possibly originating from a diseased cushion, have been obtained from the spraying trials discussed above, and they are shown in Table 12. The figures refer only to weekly harvesting treatments up to the middle of December, after which few pods were harvested, in Trial II from both control and sprayed plots and in Trial I from the former alone.

TABLE 12
*Numbers of Black pods infected at the Proximal (P)
and Distal (D) ends*

Month 1954	Proximal infections	TRIAL I			TRIAL II		
		Distal infections	(P) as a percentage of (P)+(D)	Proximal infections	Distal infections	(P) as a percentage of (P)+(D)	
June ..	(P)	(D)		(P)	(D)		
	114	165	41.7	70	99	41.4	
July ..	261	237	52.3	132	61	72.2	
	268	237	53.4	137	85	61.7	
August ..	192	98	67.7	81	31	72.3	
	112	31	79.6	61	4	93.8	
September ..	88	23	78.8	47	6	88.7	
	82	56	59.1	26	7	78.8	
October ..	100	78	61.1	41	32	56.2	
	133	70	66.4	54	54	50.0	
November ..	137	100	57.4	65	38	63.1	
	59	76	41.3	40	49	44.9	
December ..	26	19	56.8	41	18	69.5	
	16	14	51.1	26	16	61.9	

During June and July the numbers of proximal and distal infections were high. As the rainfall diminished towards August there was a rapid reduction in distal infections, which became negligible during the month. The reduction in proximal infections was not as pronounced, so that during August they represented as much as 90 per cent. of total black pods recorded.

Chemistry and commercial utilisation of beans from diseased pods

A 2½-ton quantity of dried, unfermented beans from diseased pods was used for fat extraction by normal commercial processing. Acknowledgement is due to West African Mills, Limited for processing this material and for submitting the following analytical report.

Whole Bean: Fat—45.12 per cent., Moisture—7.20 per cent., Free Fatty Acid—17.00 per cent.

Butter (samples from the expellers, filtered in the laboratory): Free Fatty Acid—17.4 per cent.

Butter (expelled, filtered (filter press) and deodorised): Free Fatty Acid—7.5 per cent., Unsaponifiable matter—0.9 per cent., Kreiss-Kerr test for rancidity—Negative, Taste—Poor, Strong after-taste, Smell—Poor, Colour—Red brown (appearance of normal solvent extracted butter).

Defatted Cake: Fat—0.57 per cent., Moisture—14.71 per cent., Theobromine (on dry fat-free)—1.14 per cent.

CAPSID STUDIES

Regeneration of Capsid damaged areas. (D. J. Taylor and F. Raw)

Several observation plots were laid down at intervals from 1946 to study regeneration of trees in capsid pockets by coppicing and by chemical control of capsids. The information obtained from these plots has now been summarised and shows that although satisfactory regeneration may be achieved by coppicing and chemical control the results have been extremely variable and the whole problem needs fuller experimental investigation.

It is proposed to lay down experiments to compare the relative value of:

- (a) protecting damaged trees with residual insecticide.
- (b) coppicing damaged trees and protecting subsequent growth with residual insecticide.
- (c) replanting.

The effect of tree age and initial severity of capsid damage on response to treatments (a) and (b) will be examined and it is hoped to study also the influence of shade and time of coppicing on treatment (b).

The chemical control of capsids raises the general problem of the persistence of insecticides under tropical conditions for in seeking to control an insect with successive overlapping generations it is essential to know for how long a particular insecticidal application retains its toxicity. A bioassay method is being used to study the persistence of DDT applied to cacao under field conditions. Our present inability to rear quantities of capsids under controlled conditions precludes their use as test insects. Pilot experiments using *Tribolium castaneum* Hbst. from standard cultures are being carried out. Later it is hoped to extend this work to include other persistent insecticides and formulations.

Chemical Control of Capsids on young, bearing Trees. (H. R. Mapother)

The commencement of a trial of 'spray painting' or 'squirting' with residual insecticides at Nankese was reported in the last Annual Report (p. 16). This has now continued for eighteen months. Five blocks of a thousand trees were severally allotted insecticidal treatments at random:

- (i) 1.25 per cent. DDT aqueous emulsion.
- (ii) 2.5 " " " " "
- (iii) 0.03 " " BHC aqueous emulsion.
- (iv) 0.06 " " " " "
- (v) No treatment.

The sprays are applied with the aid of a compressed air sprayer fitted with a lance and a special nozzle which delivers spray in the form of a solid cone of narrow angle and in relatively coarse droplets. Only the favoured resting places of the capsids are treated and the spray is delivered in short bursts to the jorquettes and branch unions. Treatment was originally applied at intervals of five months, subsequently altered to four months to allow a cycle of operations to be completed in a calendar year.

The results are assessed monthly by removing and counting damaged shoots and some confirmation is obtained by counting the capsids on a sample of the trees in each block. The numbers of shoots damaged by capsids are shown in Table 13 and, while the data are not suitable for statistical analysis, they show unmistakably that all the treatments have effectively controlled the damage from capsids. Treatment with 2.5 per cent. DDT appears to be less effective than other insecticidal treatments, but it was observed that practically all the damage and all the insects occurred in a small area near the perimeter of the out-station; this suggests that insects were invading the block from an adjacent property.

Many of the experimental trees have now grown beyond the reach of the sprayers; the final treatment reported was accordingly applied in the form of mist, using a power-operated Kiekens-Dekker mist blower; this will be used for subsequent applications. As this machine uses very low volumes of insecticide, higher concentrations are used than in spray-painting.

A small-scale trial is also proceeding to determine if, and in what circumstances treatment with DDT emulsion will damage the trees. A row of twenty trees, about 4–8 ft. high, is taken as a unit and one of the following treatments is applied to each row:

- (i) Spray-painted.
- (ii) Heavily sprayed to run off.
- (iii) No treatment.

Different concentrations of DDT aqueous emulsion are applied to successive blocks, the concentrations employed being 1.25, 2.5 and 5 per cent. At the time of writing five applications have been made at fortnightly intervals and the results so far indicate that treatment with 1.25 and 2.5 per cent. DDT is harmless however applied, but that tip scorch occurs when 5 per cent. DDT is used, especially with overall spraying.

TABLE 13
Number of damaged shoots per block

Block No.	No. of trees	Treatment	7½	Weeks from treatment										Retreatment	788	321	14*		
				4	8	12	16	21	5	10	14	18							
1	1,268	Control	1,240	120	100	106	68	112	80	32	127	103	70	130	107	Retreatment	788	321	395
2	1,162	1.25% DDT	78	0	3	33	0	0	0	6	18	13	1	17	0	Retreatment	18	0	0
5	1,114	2.5% "	18	0	1	6	0	4	0	11	40	43	6	54	2	Retreatment	27	7	0
3	1,177	0.03% BHC	137	40	120	26	0	0	0	3	7	22	3	7	0	Retreatment	19	0	0
4	1,216	0.06% "	37	0	0	10	0	0	0	5	12	17	7	9	0	Retreatment	0	0	0

* Includes mist-blowing

Simultaneous Control of Capsids and Calonectria. (D. J. Taylor and A. L. Wharton)

The treatments and routine of the field trial were reported in the Annual Report for 1953-54. During this year's work anomalous results were obtained and it has not been possible to draw any valid conclusions. The experiments were not repeated because it was found that the method of assessing damage by counting lesions was not satisfactory. Apart from the difficulty of readily identifying infected and uninfected lesions, it was found that adjacent lesions frequently coalesced and this complicated subsequent counts.

Population Studies. (D. J. Taylor)

The study of the environmental factors influencing or associated with the seasonal fluctuation of capsid populations has continued. The population estimates have been obtained regularly throughout the year from the Routine Collections and also by the intensive examination of plots of marked trees.

Routine collections have been carried out in twelve localities on successive days in the Tafo District. All the capsids which are found are collected and recorded together with the data of the number of trees, seedlings and pods which are examined. The monthly estimates of the population during the past year are given below in Table 14.

TABLE 14

		<i>Sahlbergella singularis</i>		<i>Distantiella theobroma</i>	
		<i>Adults and nymphs on pods and shoots per 100 trees</i>	<i>Adults and nymphs on seedlings per 100 seedlings</i>	<i>Adults and nymphs on pods and shoots per 100 trees</i>	<i>Adults and nymphs on seedlings per 100 seedlings</i>
April	1954	0.1	1.0	3.1	8.7
May	"	0.5	1.5	2.7	5.9
June	"	1.0	0.7	6.9	8.7
July	"	4.8	2.8	15.1	14.7
August	"	9.1	5.1	16.4	17.8
September	"	22.1	13.5	22.7	23.5
October	"	13.6	12.0	10.1	13.4
November	"	7.9	7.2	9.9	12.1
December	"	6.0	6.1	19.7	20.2
January	1955	4.6	5.9	15.1	18.6
February	"	1.9	3.2	7.9	10.3
March	"	0.1	0.6	5.3	7.9

It will be noted that *Distantiella theobroma* was generally more abundant than *Sahlbergella singularis* throughout the year, both on seedlings and mature trees. The maximum populations of both species were attained in September, after which the numbers of *S. singularis* have fallen steadily. The population of *D. theobroma*, however, after falling for two months rose again in December, and has since been followed by a gradual decline.

An examination of these data in conjunction with the meteorological records obtained at the Institute's station have shown that the fluctuations of the capsid population are related to the preceding weather conditions. A statistically significant negative correlation has been demonstrated between the monthly population estimate and the mean daily saturation deficiency of the air for the second previous month. This applies to both species; the correlation coefficient for *Distantiella theobroma* is -0.7162 ($P < 0.01$); that for *Sahlbergella singularis* is -0.6835 ($P < 0.01$).

The saturation deficiency, which is an expression of the combined effect of temperature and humidity, is a measure of the drying power of the air. Increasing values of mean daily saturation deficiency have been followed two months later by decreasing populations.

It must be stated, however, that this is only a preliminary indication of the relationship of climatic factors and fluctuations, and this in itself does not explain the fluctuation.

Certain plots were examined intensively in order to study the ecoclimate of the capsid habitat, and to investigate its significance in relation to the capsid population in a limited area. Intensive fortnightly observations on the capsid population have been made in two plots in WACRI Square Mile. One plot consists of one hundred adjacent trees of mature cacao with a complete canopy; the second consists of one hundred adjacent trees in a capsid pocket. In addition to the capsid observations fortnightly counts of possible predatory insects and of developing pods and flush have been made. Meteorological observations have been made daily in both plots.

A much higher population of the two economic species, *D. theobroma* and *S. singularis* has been recorded in the 'pocket' plot than in the 'good canopy' plot. During the course of the year over 2,000 adults and nymphs of the above species were recorded in the pocket plot compared with 105 in the good plot. The population of the comparatively unimportant cacao capsids, *Helopeltis bergrothi* and *Bryocoropsis laticollis* has been much greater in the good canopy plot. This may have been associated with the greater number of pods which occurred on the good cacao.

In the pocket plot *D. theobroma* was the dominant species. This corresponds to the difference in the relative abundance of the two species shown by the Routine Collections. The general trends in the fluctuation of both the economic species in the pocket plot were also similar to, but not so marked, as those indicated by the Routine Collections.

The meteorological observations in the two plots have emphasised the insulating effect of cacao canopy. The daily maximum temperatures have been higher in the plot where the canopy has been

destroyed. The saturation deficiency has also been greater, or in other words, the atmosphere has been drier in the pocket than under the good canopy.

It has not been possible to interpret the differences between the populations in the two plots in terms of climatic differences. Nor has it been possible, as yet, to demonstrate significant relationships between the population fluctuations and the various factors of the ecoclimate which have been measured.

The use of light-traps as a method of population sampling has been investigated. Comparative trials have shown that a modified version of the Robinson trap is more effective than the Rothamsted trap and that light from a mercury vapour discharge lamp, which is rich in ultra-violet rays, is more effective than the light emitted by the ordinary filament bulb.

A Robinson type trap incorporating a 500 watt mercury vapour discharge lamp was placed in a permanent position in the field and the nightly trapping commenced in June. Unfortunately the only available lamp was damaged five weeks later. Owing to delays in shipment and damage to consignments *en route* from the United Kingdom new lamps were not obtained until early this year when trapping was recommenced.

The trap operates from 18.30 hours to 06.30 hours the following day. *Sahlbergella singularis* has been obtained regularly in the catch, though *Distantiella theobroma* has been caught only very infrequently. *D. theobroma* is not common in the area but it appears to be less attracted than the former species. *Helopeltis bergrothi* appeared regularly in the catches during June and July but has not been found since trapping was recommenced at the beginning of the year. This, however, is probably due to seasonal variation in the population; it has been impossible to find specimens of this species in the area during the past three months.

The population estimates of *S. singularis* which have been obtained during the past three months have not shown the decline which has been apparent from the Routine Collections. However, conclusions cannot be drawn until at least one year's records are available, and the work is therefore continuing.

Capsid Reproduction. (F. Raw)

Field and laboratory studies of capsid reproduction have been started, the primary objects being: (1) to investigate the effect of food supply on reproduction and the extent to which seasonal changes in food supply may explain seasonal changes in capsid abundance; (2) to see whether egg counts provide a satisfactory method for estimating capsid abundance.

Cultural Control. (D. J. Taylor and R. Wickens)

These experiments were commenced to test the efficacy of the Belgian Congo method of capsid control, and modifications of it, in this country and to compare it with the local standard method.

The method used in the commercial plantations of the Belgian Congo consists of a regular fortnightly or monthly inspection of the cacao followed by a localised insecticidal dust application to trees on which capsids or recent capsid damage are found. The method is feasible because of the low cacao canopy which is maintained in the plantations by the regular removal of all chupons after the formation of the first jorquette. Treatments have been included in the experiments to test the effect of this pruning on yield. The local standard control measure consists of the liquid application of insecticide three times a year to the twig and branch unions of all trees by hand or spray-painting.

The first of these experiments was laid down in WACRI Square Mile on three-year-old Amelonado cacao in June 1954. The removal of chupons, the routine inspection and the subsequent dusting of recently damaged trees with 5 per cent. DDT dust have been carried out at fortnightly intervals. The liquid treatment has consisted of three applications of 2.5 per cent. DDT emulsion. Fortnightly counts of damaged shoots and capsids have been made, but yield will be the final estimate of success.

The amount of damage which has occurred throughout the experimental area has been small. A statistical analysis of the data of the number of damaged shoots which have been removed during the past seven months has suggested that the liquid treatment is more effective than the dusting treatment, and this applies to both pruned and unpruned cacao. The mean number of damaged shoots removed per hundred trees (pruned and unpruned) during the period of seven months is, for those which have received liquid treatment, 155 and for those which have been under the dusting treatment, 248 (S.E. = ± 27.2). However, this preliminary result cannot be considered conclusive, particularly as it has not been possible to demonstrate differences between the numbers of capsids found in the plots under the different treatments. The mean number of capsids found per hundred trees under all treatments during seven months is eighty-two.

A second experiment, in which the treatments are similar to the first, was laid down at Akwadum substation on four acres of two-year-old Upper Amazon cacao in August 1954. However, as many of the seedlings had not jorquetted at that time it was decided to defer the experimental insecticidal treatments until the end of January 1955. The removal of developing chupons in the appropriate

plots has been carried out regularly since the experiment was laid out. As yet there are not sufficient data available to warrant an analysis.

A feature of this method of capsid control apart from its effectiveness in the Belgian Congo, is its economy in labour and materials. It was considered desirable therefore to find out the approximate cost of the method when applied to an area of regularly spaced cacao in the Gold Coast.

Two acres of young cacao which had regenerated from trees coppiced in 1952, were taken over in May 1954. At that time most of the young trees had formed a jorquette from which, in many cases, a leading chupon had developed. The trees were regularly spaced in lines at approximately 7 ft. by 7 ft. The Dusting and Pruning method of capsid control commenced in June 1954 with removal of all chupons above the first jorquette, and an initial general application of 5 per cent. DDT to all trees at the rate of $7\frac{1}{2}$ lb./acre. Inspection for fresh capsid damage, the removal of developing chupons and the localised insecticidal dust application to recently damaged trees have been carried out at fortnightly intervals. The insecticide has been applied with a hand-operated rotary fan dusting machine.

During the course of the nineteen fortnightly treatments which have taken place since the trial commenced an average of twenty trees per acre per fortnight have been dusted, though only on five occasions did the number exceed twelve per acre.

The average requirements of labour and materials for the past nine months have been as follows:

Inspection, removal of chupons and				
damaged shoots	..	..	..	9 man hours/acre/month
Dusting operations	..	..	..	1 man hour/acre/month
Quantity of dust used (5 per cent. DDT)				2 lb./acre/month
Cost of the labour at 4s. 6d. per eight				
hour day	..	..	..	5s. 8d.
Cost of 2 lb. 5 per cent. DDT	..			1s.

Thus the cost of materials and labour, excluding supervision, for this method of capsid control in regularly spaced cacao at a density of 872 per acre is 6s. 8d. per month. This is equivalent to 7s. 10d. per 1,000 trees.

ESTABLISHMENT AND MAINTENANCE

(R. J. Benstead and R. Wickens)

Establishment Trials (including Shade Trials and Observations)

It was reported (Benstead and Wickens, *Ann. Rep. WACRI* 1953-54, pp. 36-39) that the First Establishment Experiment had demon-

strated the superiority in yield of basket seedlings over bare-root seedlings and plants sown at stake. In 1954-55, when the trees were seven years old, the yields have been almost identical with those of the previous year except that plants sown at stake have shown an increase of 54 per cent. But this represents an increase of only 9 lb. dry cocoa per acre, which is of little importance. At this period in the life of the trees an increased annual yield is to be expected and it is disappointing that it is actually static. However, the yields of mature cacao trees on the Institute's land have been well below average and the lack of significant yield increase in this experiment may be partly a seasonal effect.

The treatments in the Second Establishment Experiment are: (i) tree cassava temporary shade followed by indigenous, naturally occurring, forest tree shade; (ii) secondary bush temporary shade, followed by *Gliricidia* permanent shade at 8 ft. by 8 ft.—the cacao in this treatment is to be pruned to one tier of branches; (iii) secondary bush temporary shade followed by indigenous shade as in (i). The cacao was planted as seed at stake in 1948 at 8 ft. by 8 ft. and was first pruned in August 1954. Variation in the very low crop this year (35.4 lb. dry cocoa per acre) has been as great between replicate blocks as between treatments.

In the Third Establishment Experiment cacao was planted as seed at stake (three beans per piquet) in 1952 after a succession of varying plantings of temporary shade plants. No secondary bush had developed on this area subsequent to the death from Swollen Shoot disease or removal by cutting-out of the original cacao population. A ground cover of colonising species was present. The treatments consisted of: (i) tree cassava shade with the addition of volunteer or planted cocoyams between the rows of cacao; (ii) the replacement of the tree cassava by plantains at the same 10 ft. by 10 ft. spacing and (iii) two crops of maize, the later one as a temporary shade supplemented by a crop of edible cassava. *Gliricidia* was planted throughout to form a semi-permanent shade. The local farming practice of clear felling and burning was not used in the food crop plots since the harmful effect of this treatment before cacao establishment was well known. Overhead shade of desirable species was preserved where it existed, and strips of untouched ground vegetation containing a reservoir of saplings were left uncultivated between the cacao rows in all treatments. As a direct result of leaving the top shade the growth of the food crops was poor and the yields from these and the revenue obtained from them were negligible. The cacao plants have not yet been thinned and the number of completely vacant piquets is negligible. A comparison of total surviving plants shows that survivals from the three treatments are not significantly different from each

other and have a mean of 62.3 per cent. This is an average of nearly two plants per piquet, which will give ample material for a full stand after final thinning. There is, however, a significant difference between the survival in three of the blocks and that in the other three (70.2 per cent. against 54 per cent.). The three blocks which show the higher survival rate are those where the top shade is more adequate and this fact seems to emphasise the need for preserving such shade in the establishment of cacao. Although cacao has been established in association with food crops the conditions under which both were grown were biased in favour of the cacao to such an extent that an adequate return from the food crops was precluded.

To obtain the final results of the Transplanting Experiments the survival of plants after the second dry season in the field was recorded. A count was made in March 1955 and Table 15 shows the result in terms of mean percentage losses of each of the treatments.

TABLE 15

Mean percentage losses of seedlings after the second dry season in the field

<i>Site of Nursery Beds</i>	<i>Site of Field plots</i>	<i>Age of seedlings at time of transplanting in months</i>				
		8	7	6	5	4
Oyoko	Oyoko	35.7	31.5	27.1	17.8	35.4
Tafo	Bunso	41.1	29.5	20.9	16.4	15.8
Bunso	Bunso	29.5	17.7	11.1	13.2	10.5
Bunso	Tafo	30.6	17.8	11.9	14.3	8.0
Tafo	Tafo	26.1	30.1	23.3	12.5	12.0
Mean						
All Sites		32.6	25.0	18.4	14.8	15.4

(Detransformed angular values)

Statistical analysis shows that the age of the seedlings at the time of transplantation is a significant factor influencing survival at Tafo and Bunso but not at Oyoko. In general, survival of seven- and eight-month-old seedlings is much inferior to that of four- to six-month-old seedlings and transplanting practice should be guided accordingly.

At Bunso, as the table shows, locally grown transplants survived to a significantly greater extent than those from Tafo, and it might be concluded that the effect of transport even over this short distance (ten miles) was harmful. At Tafo, however, locally-produced transplants suffered a greater mortality than those introduced from Bunso. It appears that this difference is connected with the nature of the nursery beds at the two places. The beds at Bunso were on mid-slope soil with some humus content, whereas the beds at Tafo were on sandy soil, which, while it facilitates removal from the beds with

minimum root damage, does not adhere to the plants, the roots of which therefore tend to dry out quickly during handling. It would thus be reasonable to expect that transported seedlings from Bunso, by retaining some moisture-holding soil, would show markedly lower losses than transported seedlings from Tafo.

Comparison of Table 15 with Table XI on p. 38 of the Annual Report for 1953-54 shows that valid comparisons of survival rates may be made after the first dry season in the field. Accordingly a large-scale transplanting trial planted in 1954 can already be regarded as a valid demonstration of the best transplanting technique. Some four thousand four-month-old Amazon seedlings were transplanted immediately after careful fork-lifting from the nursery beds into freshly-opened holes, just large enough to take their roots. The beds were watered before the seedlings were lifted and, in the field, the soil was tamped around the transplants under strict supervision. Planting was restricted to the early morning unless it was raining later in the day. Despite a protracted 'short-dry' season during July and August soon after planting and a severe late 'harmattan' season in January and early February the total losses to date amount to only 203 seedlings.

The choice of sites for nursery beds may be difficult. An adequate supply of water is necessary for dry season irrigation and this in itself may be an overriding consideration and necessitate the siting of the beds on valley bottoms in the vicinity of permanent streams where sandy or clayey soils are usually to be found. Sandy soil will naturally be favoured because of the extreme difficulty of lifting seedlings from the heavy clay. If, however, the water supply problem is not great the use of soils of the mid-slopes, or possibly even those of the hilltops, may well ensure a higher plant survival, particularly if the seedlings are to be transported any distance. It seems likely that Amazon seedlings are less demanding in their requirements than Amelonado seedlings. In all there must be a compromise between easily worked soils on the one hand and soils with a certain measure of water retaining capacity on the other. This compromise might be attained by heavy dressings of organic mulches.

Spacing Trials.

The spacing experiment planted with West African Amelonado cacao in 1947, which compares tree densities per acre from 200 to 2,800 in a randomised block design (*Ann. Rep. WACRI* 1947-48, pp. 77-80) has produced a measurable crop from all treatments for the past two seasons. A valid relationship between tree density and yield as measured by pods per tree or by pounds of dry cocoa per acre has been established. Table 16 shows these values.

TABLE 16

Expected yields per tree and per acre from six- and seven-year-old Amelonado at varying stand densities

Trees per Acre	Yield in 6th year		Yield in 7th year	
	Pods per tree	Dry cocoa per acre (lb.)	Pods per tree	Dry cocoa per acre (lb.)
200	4.59	74.8	8.36	149.3
400	1.98	70.7	3.70	131.9
600	1.28	68.3	2.29	122.7
800	0.94	66.8	1.63	116.5
1,000	0.74	65.6	1.25	111.9
1,200	0.60	64.6	1.01	108.4
1,400	0.51	63.8	0.84	105.4
1,600	0.44	63.1	0.72	102.9
1,800	0.39	62.6	0.63	100.8
2,000	0.35	62.0	0.56	99.0
2,200	0.31	61.6	0.50	97.3
2,400	0.29	61.1	0.45	95.8
2,600	0.26	60.8	0.41	94.4
2,800	0.24	60.4	0.37	93.1

While the table shows that both pods per tree and yield per acre decline with increasing tree density and is self-explanatory so far as gross return per acre is concerned, there are two further economic considerations involved viz., weed growth and capsid damage, both of which are affected by the tree density (*Quart. Prog. Rep. WACRI*, No. 36, p. 12, 1954). The abundance of the ground vegetation was determined by quadrat sampling during January 1955, when weed growth was at a low level. At the same time an assessment of capsid damage was obtained by counting the number of trees in each plot which showed capsid damage, no matter how slight. The results were as follows:

TABLE 17

	No. trees per acre		
	200-400	600-1,000	1,200-2,800
lb. green matter per acre	1,432	189	51
No. trees damaged by Capsids (%) ..	32.4	15.9	7.9

It is impossible to base economic considerations on these figures; the abundance of ground vegetation would not be directly proportional to the cost of weeding, nor would the extent of capsid control measures be directly proportional to incidence of damage. Direct observations on these costings will be necessary during the coming season.

This rather unexpected decline in yield with increasing tree density suggested the necessity of examining the effect of tree density on the performance of mature cacao. Thirty-two plots of individually recorded trees on the Old Station, each one-quarter of an acre, were selected for this purpose. Data for 1938-39 (a year of high yields) and 1947-48 (a year of low yields) were examined. This cacao is reputed to have been planted in the mid 1920's and, while the trees are not regularly spaced, their density ranges from 200 to 1,000 per acre.

An exponential relationship of the same type as that found in the experiment described above was established. In both years there was decreasing yield per tree with increasing density. However, with mature cacao, the decrease in yield per tree was not so great as to result in a lower yield per acre and in fact the highest yields per acre were obtained from trees at the greatest density. These effects were much more marked in the year of generally low yields.

The trees in the spacing experiment with Upper Amazon cacaos have made excellent progress during the year, all the 8 ft. by 8 ft. and many of the 10 ft. by 10 ft. plots now have a closed canopy in their sixth year from seed. This early closing of the canopy is particularly evident in the pruned plots. The yields (Table 18) have not shown a marked increase on those of last year and the significant superiority of the pruned plots is not repeated.

TABLE 18
Yields from Upper Amazon Spacing Experiment (1954-55)

Spacing	8' x 8'	10' x 10'	12' x 12'
Equivalent tree density/acre ..	680	436	302
Unpruned plots			
Pods per tree	4.92	6.56	9.09
Dry cocoa per acre	298.7 lb.	255.4 lb.	245.1 lb.
Pruned plots			
Pods per tree	4.71	6.76	9.20
Dry cocoa per acre	286.0 lb.	263.2 lb.	248.1 lb.

There is a significant difference in pods per tree when 8 ft. by 8 ft. and 12 ft. by 12 ft. spacings are compared. This fact is relevant when seed multiplication gardens of this cacao are being established. The object of such gardens is the maximum production of new planting material per mother seed available and this experiment demonstrates that, at least under the favourable growing conditions at Tafo, maximum productivity can best be achieved by wide spacings. Thus with both Amelonado and Upper Amazon cacao maximum productivity per tree is obtainable with the widest of the spacings examined in each case.

Comparative yield trials of seedlings and rooted cuttings

The first replicate block of an experiment designed to compare the growth and yield of basket seedlings from hand-pollinated pods and of rooted two-leaf fan cuttings of Amelonado (A196), hybrid (TF1) and Amazon (T60) cacaos has been planted. Three spacings appropriate to low, medium and high density for the tree types have been used. Two more replicates remain to be planted in 1955. The 'bush-traverse' method (Benstead, Proc. W.A. Int. Res. Conf. 1953, in the press) is being used, but the area chosen for the experiment is far from uniform in its secondary bush development. The block already planted shows a particularly diverse vegetation. Side shade consists of a wide range of shrubby and herbaceous species. Intermediate shade is provided in places by *Solanum verbascifolium* and bananas while in others by old cacao and *Carapa procera*. Top shade is provided by widely spaced trees, mostly species known to be suitable for this purpose, but on the whole is too sparse except where oil palms are dominant. Unexpected difficulties were encountered in the establishment of the rooted cuttings and 28 per cent. losses have been sustained. There is no evidence that any one cacao type is more susceptible than the others and deaths may be associated with plants which were less well developed at the time of planting. Losses of seedlings have been only 2 per cent.

Effect of soil type on pod development and yields of cacao

Data have accumulated since 1951 from a series of twenty-five sample plots of twelve trees each on a range of soil types represented at Tafo, in an attempt to correlate the performance on various soil types with some of the characteristics of those soils. The data consist of soil analyses for major nutrients, monthly soil moisture determinations and soil water table observations, number and size classification of pods on the trees month by month during development and at picking, and total crop in terms of pods per tree and wet weight of cacao per tree. The soil types are those occurring in the hilltops (Wacri and Koforidua series), mid-slopes (Nankese series) and valley bottoms (Asafo and Akwadum series) which have been developed over granodiorites.

TABLE 19
Mean yield in pods per tree on various soil types

Year	Soil type					
	Wacri	Koforidua	Nankese	Asafo	Akwadum	Mean
1951-2 ..	20.83	26.95	11.47	—	19.56	19.70
1952-3 ..	14.07	17.88	14.87	17.20	21.72	17.15
1953-4 ..	16.11	18.12	12.72	15.35	18.90	16.24
1954-5 ..	12.00	13.95	10.07	10.43	16.87	12.66
Mean ..	15.75	19.22	12.28	14.33	19.26	16.44

Preliminary analysis of the data indicated the non-significance of differences between soil types and of their interaction with the years. The pattern of yields was not what was expected since Akwadum series, generally taken to be an example of a 'bad' cacao soil (Charter, 'Cacao Soils Good and Bad', cyclostyled, WACRI 1947) has produced such persistently good yields. Recent work on the relationship between yield per tree and stand density prompted a re-examination of the yields after correction for density. Stand density on these plots ranged from 160 to 570 trees per acre, and a near significant correlation of -0.3141 ($n=23$) was obtained between the logarithm of yield and that of density. The corrected mean yields are then as follows:

TABLE 20
Mean yield in pods per tree corrected for stand density

Pods per tree	Soil Type				
	Wacri	Koforidua	Nankese	Asafo	Akwadum
	15.68	12.75	14.85	15.17	18.71

Thus the adjustment for spacing has accounted for the large discrepancy between Wacri and Koforidua series, which was unlikely to be explicable in terms of soil differences since they are so similar in many respects. It has not, however, accounted in full for the high yields from the Akwadum series plots and this must be regarded provisionally as a true effect. Much more work is required, particularly by correlation analyses bringing in the soil characteristics, and also an examination of the forest tree complexes occurring on the various soil types and their effect on yield.

Methods of Crop Forecasting

Records have been kept for the four crop seasons since 1951 of the number of pods borne by trees in eighty one-fortieth acre sample plots on the Institute's land at Tafo. Monthly counts have been made and the pods on the trees have been classified as less than 3 in., between 3 in. and 5 in. and over 5 in. in length. The total number of diseased and wilted pods has also been recorded. The number of good and discarded pods at harvest and the respective wet weights of the beans have been recorded. The data have been summarised and an offer by Mars Ltd of Slough, England, has been accepted to undertake some of the tedious computing which is necessary to determine the magnitude and significance of the relationships between the number of pods in the three size categories and the final yield of the plots. The work is incomplete but the analyses of the 1951 records showed significant results. However, it appeared that as good a 'prediction' could be obtained by the use of the total of the three pod

categories as with them separately. The use of a single variable instead of three would simplify the operation of any practical scheme of forecasting if it should prove possible to develop the work.

Resulting from discussions with the Gold Coast Meteorological Service it was decided to examine the relationships between the yields of cacao from the thirty-two one-quarter acre plots on the Old Station of which individual tree records are kept, and climatological data for corresponding years. Initially a promising non-linear correlation was established between the yield of the plots in any one month and rainfall of the fourth previous month, i.e., between April rainfall and August crop and between July rainfall and November crop, or in other words for months when the rainfall is likely to be marginal. However, analysis by Mars Ltd showed that there was no evidence of relationships between the rainfall of any month and any succeeding crop up to five months later.

Effect of Removal or Retention of Chupons on rooted Cuttings

An area of land previously under young seedling cacao at 8 ft. by 8 ft. has been cleared and planted with rooted two-leaf fan cuttings of four types of cacao at an approximate spacing of 11 ft. by 11 ft. This material is to be used to compare the yield of pruned and unpruned cuttings in a simple randomised block design. Although shade conditions appeared almost ideal for seedling material, i.e., well-grown *Gliricidia* and a full ground cover of herbaceous species, with a preponderance of cocoyams, about 10 per cent. of the seedlings have been lost. These losses reinforce the need mentioned earlier for more experiments to determine the optimum establishment conditions for this kind of planting material.

SOIL FERTILITY AND MANURIAL REQUIREMENTS (S. N. Adams)

Introduction

Work during the past year has been largely concentrated on the field trials on 1953-planted Amelonado seedlings. Details are given below, but the following is a summary of the present situation.

Growth on one trial, at Goaso, has been greatly superior to that on all other sites. It follows, therefore, that growth at these other sites has been limited by soil or environmental factors. The limiting factor has not been discovered by the NPK trials for, apart from one small but significant response to superphosphate, no responses have been obtained. Analysis of leaf samples from two local trials has shown significant absorption of fertilizer P at two sites and of fertilizer N at one. This suggests that failure to absorb fertilizer is not the factor inhibiting response. No relation has been found between cacao growth and analysis of the top-soil.

Effect of Major nutrients

(1) The fertilizer trials on the twelve four-acre Amelonado plots established in the rains of 1953 have in some cases been modified owing to dry season losses and damage due to muriate of potash. The present position is summarised below:

- (i) Trials started in October 1953 and continued unchanged: WACRI (two sites), Oyoko, Poanu, Goaso, Aiyinasi.
- (ii) Trials damaged by muriate of potash: Bunso, Biene, Juaso. New Trials were started in April 1954 on other parts of these four acre plots.
- (iii) Trials wholly or partly wiped out by drought during the 1953-54 dry season: Kwadaso, Bechem, Akaa. No fertilizer work is conducted on these plots at the moment.

Routine fertilizer applications were made on the nine remaining trials in April and September 1954. The rates of application were as follows:

N=2 oz. sulphate of ammonia per picquet per application

P =2 oz. superphosphate " " " "

K =0.5 oz. sulphate of potash " " " "

Height of seedling is used as a measure of performance and is taken every three months. On this basis, only one significant response (to superphosphate at Poanu) has been observed. It is appreciated that seedling height may not be a good criterion of performance, and work has been started to relate seedling height to fresh weight. Moreover, early vegetative growth may not influence the ultimate criterion of bearing age and rate, but this point cannot be elucidated for some years.

To see if shade is responsible for the lack of response, three out of the six blocks on the trials at WACRI and Bunso are being gradually denuded of shade.

Six four-acre sites for future trials have been selected at Apedwa, Asikuma, Foso, Buaku, Fumso and Wamfie cocoa stations. The first four were planted in the rains of 1954 and the last two will be planted in 1955. No NPK trials will, however, be started on them until the reasons for the lack of response on the existing trials have been examined.

(2) Work has been continued on the 23 factorial NPK trials on Amazon Plots at Asokore, Jumapo, Bunso and Anyinam. Routine fertilizer applications were made in April and September 1954, the rates of application being as follows:

N=8 oz. sulphate of ammonia per tree per application

P =8 oz. superphosphate " " " "

K =2 oz. sulphate of potash " " " "

1954-55 crop yields have been taken by members of the staff of the Department of Agriculture on these plots. The crop year was deemed to have ended on 31st March and the results have not yet been assessed. Girth measurements are taken on the trees every six months but no response to fertiliser has been observed in this way.

(3) The Department of Agriculture has completed yield recording of the 1954-55 harvest of the fifteen mature peasant farms selected for future manurial trials. No experiments will be laid down on these farms until 1956 at the earliest.

Effects of Major Nutrients from different sources

Routine work and harvesting have been carried out on the 'types of nitrogen' trial at Nankese and 'types of phosphate' trial at Kabu Hill. The results have not yet been assessed.

Examination of effect of nitrogen and phosphate on Farmers' Cacao

Considerable difficulty has been experienced in selecting a suitable site for this experiment and none of the numerous farms examined in the Tafo district presented sufficiently uniform conditions to give any prospect of success. It is possible that more efficiently managed farms in Ashanti may be suitable and this possibility is being examined.

Soil analyses

Soil profile samples were taken from the control plots of the NPK trials on 1953-planted Amelonado. The surface soil has been analysed for organic matter, total nitrogen, C/N ratio, total exchangeable bases, pH and sticky point. No relation whatsoever was found between cacao performance and any of these factors. It is believed from observation that 'shade' has a profound effect upon the performance of the seedlings. If this is so, it would obscure relations between soil analysis and performance.

Characters of good and bad soils

Apart from monthly moisture content determinations no further analysis has been done on the soils of the Agronomist's 'Performance of Cacao on Different Soil Types' experiment. No relation between soil analysis and performance has been found and again there is the difficulty of the effect of 'shade'. It seems probable that until further investigation of the role of shade has been made, the relation of soil types to productivity will remain obscure (see p. 91).

Uptake of nutrients

Samples consisting of eighteen recently-hardened leaves were taken from each plot of the NPK trials on Amelonado seedlings at WACRI and Bunso. Analysis for N and P indicated significant absorption of fertilizer P at both sites, and of fertilizer N at Bunso alone. These results suggest that the failure of these trials to show response is not due to inability to absorb applied fertilizer.

Minor elements

A microplot experiment to test the responses of seedlings to minor elements in the field is proposed for the 1955 rainy season.

ROOT STUDIES

(A. D. McKelvie)

Fungus-Root associations

The experiment described in the last report was completed. No difference in growth was observed between plants in sterilised and unsterilised soils. A second experiment on the same lines produced a similar result.

Root distribution

Due to the time-consuming nature of the work, relatively few root systems have been excavated during the year. It is sufficient to summarise at the moment that trees in heavy clay or in sand with a high water-table have a long thin tap-root, superficial lateral roots and a well-marked surface mat. Trees on well drained soils have a short thick tap-root, a deeply set lateral root system and a mass of well-distributed fibrous roots not forming a mat.

Cacao seedlings have been grown in conjunction with forest tree seedlings but no effect on growth has been observed. This is being continued with grasses and food crops.

VEGETATIVE PROPAGATION

(J. F. Archibald)

Simplified Techniques

Further trials of the wooden frames described in the previous report were carried out during the period. During the wet season, rooting results were comparable with those from the conventional type of propagating unit.

A further series of experiments is being carried out to simplify propagation still further. A bed of soil 6 ft. by 3 ft. and 6 in. deep was made up under split bamboo shade. This was well watered and a hundred two-leaf cuttings of the clone S36 were set with the stems obliquely in the soil, so that the leaves lay on the soil surface. The usual 'quick-dip' application of β indole-butyric acid was used. The cuttings were covered with polythene sheet, laid directly over the leaves, and weighted at the edges. No further watering was necessary. At the end of one month from the time of setting the cuttings were lifted. Of a hundred cuttings set, fifty-seven rooted, two died and there were forty-one healthy, unrooted survivors.

While it cannot be assumed that the forty-one survivors would subsequently produce roots, the fact that fifty-seven plants did produce roots in the arbitrary period of one month and that only two

died shows that this method compares favourably with the standard technique.

The polythene sheet used for this method of rooting cuttings is relatively strong, chemically inert, does not support fungal growth and therefore can with care be used for a considerable number of sets of cuttings. The cost of the material for this experiment was 19s. 6d. As no further watering was required it took only three man-hours for the whole operation from making up the bed to the potting of the cuttings.

Improvement of Methods

As described in the previous report an experiment was started in which 180 cuttings of each of three clones were set at monthly intervals from April 1953 to June 1954. The clones R15, TF1 and P30 were rated, from routine propagation records, as 'good', 'medium' and 'poor' rooting types respectively. In each set, sixty of the cuttings had a ring of cortical tissue on the petiole killed with xylene, sixty had a ring of the cortical tissue removed, while the remainder were untreated. Counts were made of the number of cuttings rooted and the mean number of roots per cutting. It was found that the time of the year at which the cuttings were set markedly affected the rooting of all clones, the main difference being between those set in dry and wet seasons. The total number of cuttings rooted from R15 was greater than either of the other two clones ($P = .01$). The poor rooting of TF1 was due to a sharp drop in the numbers rooted at the beginning of the dry season. The mean number of roots per cutting varied directly with the time of year at which they were set to a significant extent in TF1 ($P = .01$) and P30 ($P = .05$). The fall in the number of roots produced again coincided with the onset of the dry season. Removal of a ring of tissue mechanically from the petiole of the cuttings of P30 increased significantly the number of roots per cutting and the number of cuttings rooted, compared with 'chemical ringing' and 'no ringing' ($P = .01$ and $P = .05$ respectively). The mean number of roots per cutting was positively correlated with the number of cuttings which rooted on each occasion for the clones TF1 and P30 ($P = .01$).

In general, it appears that different clones, even when grown under reasonably uniform conditions, have characteristic rooting performances. In addition there is considerable variation between different sets of cuttings from a particular clone. This is apparently due to climatic conditions influencing the parent tree, and thus the cutting taken from it, or to the environmental conditions under which the cutting is rooted. The same factors which influence the initiation of roots also influence the number of roots produced: thus a clone which is difficult to root will, on the whole, have a poor root system.

PLANT BREEDING AND SELECTION
(H. H. Rogers and R. Knight)

Progeny and Introductions Trials

As in previous years all trees have been individually recorded. The pods from each tree were classified into healthy, rodent damaged and black pod diseased. In some areas a further division was made between pods borne on the trunk and those borne on the branches. Harvesting is carried out at weekly intervals in all areas. The wet weight for each selection is recorded together with the number of beans per pound wet weight. The beans of a number of the selections have been fermented and used for chemical analysis and quality tests.

The Progeny Trials and Introductions have given yields very close to those of the previous year, once again behaving similarly to adjacent areas of the Gold Coast. The First Clonal trial has produced 50 per cent. more pods, whilst the Second Clonal trial has doubled the yield of the previous year. It is not intended to give details of statistical analyses in this report as these will appear in other publications but the performance of the better selections is listed in Table 21.

TABLE 21

Area		Selection	Age from planting in field (years)	Discarded pods as % of total pods harvested	Yield lb. dry cocoa/acre (computed)
2nd P.T.A.	..	E1	13	24.5	750
10' x 10'	..	TF1		26.4	690
		A72		22.9	580
1st Clonal	..	ACU85	8	2.2	800
10' x 10'	..	A12		5.6	675
		A73		8.5	600
2nd Clonal	..	R15	6.5	1.0	930
8' x 8'	..	S21		Nil	530
		TF1		1.8	380
Introductions	..	T60	10	19.8	1,350
14' x 14'		T76		16.4	1,150
		T79		15.3	870
		T85		10.5	730
		T63		13.3	725
		T72		12.4	720

In the Eighth Progeny Trial (planted 1952) the hybrid selections continue to grow vigorously. A few pods have been harvested and the beans fermented using the method, with a slightly modified apparatus, of Wadsworth and Howat (*Nature*, **174**, p. 392, 1954). During the year the planting of the Ninth Progeny Trial was completed and establishment has been very good; differences in vigour are already showing between selections.

In the coming year it is proposed to plant a Third Clonal Trial. The bulk of the selections for this trial are from the Upper Amazon Population and the remaining selections are the best from the First and Second Clonal Trials.

Although the number of trees removed with swollen shoot disease from the Plant Breeding Trials was 194, the number of new outbreaks was less than in the previous year. The first outbreaks were recorded during the year from the clonal trials there being three in the First Clonal (seven trees) and one outbreak in the Second Clonal (two trees).

Breeding programme

During the year no further selections for seed production were made in relation to the breeding programme. The following clones for the Third Clonal Trial were selected and cuttings were taken:

T12: 113	T72: 1,767
T16: 613	T76: 1,224
T60: 885	T79: 416
T60: 887	T79: 467
T60: 1,774	T79: 501
T63: 882	T85: 799
T63: 967	ACU: 85
T63: 971	R15

Growth and yield trials

The planting of the nine Series I Variety trials (*vide Ann. Rep. WACRI* 1953-54) has been completed and establishment is very good. The first growth records are now being taken. Of the Series II trials the first has been planted at Bunso Plantation and hand-pollinated pods will be supplied for the remaining eight trials during the coming year. The proposed sites for the Series II trials are listed below:

Eastern Province: Apedwa, Bunso, Oyoko, Pankese.

Ashanti: Fumso (Brofoyedru), Mampong, Wamfie.

Western Province: Asikuma, Foso.

Performance of Herrania and Theobroma spp. and interspecific crosses

Several trees of *T. microcarpa* came into bearing for the first time since their introduction from Trinidad in 1944. Some of the beans were analysed for fat while others were used to test the susceptibility of the species to swollen shoot virus.

Further attempts were made to hybridise *T. cacao* and the related species of *Theobroma* present at Tafo. Seedlings obtained from the cross *T. cacao* x *T. angustifolia* are now nine months old but are very slow-growing.

Pollination

Studies of the mechanics of pollination have been limited. To date two self-compatible plants have been found in the five acre block of E1 at Bunso plantation. It is not considered that these two plants contributed significantly to the amount of setting taking place in this isolated plot of the self-incompatible E1 clone.

Incompatibility

The working out of the genetic system governing incompatibility in the Upper Amazons has now been completed for all the selections at Tafo. The study of populations containing self-compatible trees is now far advanced and it is expected to formulate a genetic hypothesis covering these types during the pollination season of early 1955. Most of the work is now concentrated in the Eighth Progeny Trial which contains crosses between Upper Amazon and local self-compatible selections. A second publication on incompatibility will contain the results of this work.

Genetics and morphology of hereditary characters

A large number of pod and floral characters have been tabulated in the study of the genetics and morphology of hereditary characters of cacao. This work is as yet far from complete.

Polyploidy

Polyploids of *T. cacao* and three related species have been produced by treating young seedlings with colchicine. The first treatment of seedlings was made in October 1953. The resulting tetraploids have been intensively studied for differences with normal diploid *T. cacao*. A full account of this work is being prepared.

TABLE 22

<i>Clone Collection</i>		<i>Clone Collection</i>	
<i>Number</i>	<i>Selection</i>	<i>Number</i>	<i>Selection</i>
C13	ACU85	C43	T60:888
C14	W41	C57	T60:1,774
C15	SC1	C62	T12:26
C16	R15	C63	T12:63
C17	D4/4/4	C64	Na32
C18	P4/9:J11:4:5	C65	Pa35
C19	S72:J11:4:47	C67	T79:501
C20	S72:J11:4:49	C68	T79:416
C21	P3/7:J10:4:46	C69	T79:467
C22	E9:B3:1:195	C70	T12:113
C23	E1:C4:3:270	C71	T12:150
C24	K5:C4:4:353	C72	T12:151
C25	E1:C4:3:291	C73	T16:613
C26	E1:J9:2:70	C74	T63:971
C27	S84:E10:4:90	C75	T63:967
C33	X40	C76	T86:982
C36	S21	C77	T85:799
C37	A73	C78	T72:1,767
C38	A12	C79	T76:1,224
C40	T60:885	C80	T63:882
C42	T60:887		

Nucleus plots

Considerable progress has been made in establishing clone collections at Juaso and Poanu. In addition a third clone collection is being established at Bunso Plantation.

The Department of Agriculture, Gold Coast, will shortly complete the propagating-station building programme where it has been decided to establish nucleus plots of all clones which in the near future may be used for seed production or for clonal plots. Approximately twenty stations will have small plots of the clones listed below. Any clones which fail to gain final approval will be eliminated. Material is also to be sent to the Department of Agriculture, Nigeria.

FERMENTATION AND QUALITY

(R. Wickens)

Effect of Ripeness and Storage of Pods in relation to Quality

A report, which will form the basis of a publication, is in the course of preparation embodying the results of intermediate and field scale experiments, including those carried out under this heading, and others as described in previous Annual Reports (*Ann. Rep. WACRI*, 1950-51, pp. 57-58, 1951-52, pp. 47-48). The report will examine those 'quality' components which are associated with seasonal, varietal and climatic factors in addition to a comprehensive description of the more formal approach to the problem by means of experiments.

Survey of Farmers' Fermentation Methods

A questionnaire has been drawn up and contact made with the Agronomy Branch of the Cocoa Division of the Department of Agriculture with a view to the selection of a sample of farmers in the Eastern Region for the survey during the coming season.

Taste Panel Studies for Evaluation of Quality

Previous taste panel work in WACRI has been reported by MacLean and Wickens (*Rep. Lond. Cocoa Conf.* 1951, pp. 124-126; *Ibid.* 1953, pp. 34-39) and Wickens (*Ann. Rep. WACRI* 1952-53, pp. 34-35). A feature throughout has been the use of control samples prepared locally according to a recipe made available by the British Food Manufacturing Industries Research Association, but differing at the request of the local panel in that the samples were not sweetened (MacLean and Wickens, *Nature*, **168**, p. 434, 1951). The procedure was to dry the beans for one hour at 95-100°C. and to roast them in double jacketed tubes in a glycerine bath. Uncut beans were roasted for sixty minutes and cut or broken beans for fifty-five minutes. The shelled beans were then ground by hand in a mortar

until the sample appeared smooth to the palate. Final mixing took place on a sheet of glass using a palette knife and was continued until the chocolate began to cool and thicken. It was run off into moulds and refrigerated for at least three days before tasting. Through the courtesy of Messrs Cadbury Brothers and the British Food Manufacturing Industries Research Association, chocolate samples were received which were agreed to be representative of good Amelonado flavour. These chocolates were employed as a standard in subsequent flavour appraisals. The preparation of test samples was modified to make them more nearly comparable to the standard. The ingredients were: nib—ten parts, sugar—thirteen parts, deodorised cocoa butter—four parts. The sugar was ground for five minutes in an end-runner mill and was then run through a mincing machine with the other ingredients. Germ-free nib was used since experience showed that this enabled a smoother chocolate to be produced. After mincing, the mass was ground in a hot mortar in the end-runner mill for forty-five minutes. Finally the milled liquor was tempered in an electric food mixer with a heated bowl for twenty minutes.

The taste panel has been enlarged during the past year. In the past the panel has comprised those members of the staff who, by virtue of a long association with cocoa production, were presumed to have fairly discriminating palates in this direction. However, such discrimination is likely to be more relevant to making comparisons of raw beans rather than chocolate liquors as is evidenced by their own preference for unsweetened samples. It seemed appropriate to recruit new panel members and as a preliminary, to test the consistency of their judgement. The first taste panel had as its members all the Research and Administrative staff and their wives and the first tests took the form of a uniformity trial. One sample only was used throughout and it was issued to tasters, of whom there were twenty, as eight pairs of coded samples for stating in the mornings and afternoons of four days. Tasters were asked to divide twenty marks between the samples, the distribution of the marks to indicate the extent of their preferences. The sample used was prepared by Messrs Cadbury Brothers Limited.

The results were tabulated in terms of pair differences in the first instance but it became obvious that a wider class interval than this was necessary and the accompanying table was drawn up by arranging the differences into groups of three, i.e., -15 to -9 , -9 to -3 , -3 to $+3$, $+3$ to $+9$, $+9$ to $+15$ and reducing to percentages. Owing to the absence of some tasters on some occasions a total of only 149 observations was available.

TABLE 23

Percentage number of observations in each pair difference group

		<i>Pair difference</i>				
		-15 to -9	-9 to -3	-3 to +3	+3 to +9	+9 to +15
Morning sessions	..	2.7	16.0	44.0	30.7	6.7
Afternoon	..	2.7	18.9	43.2	25.7	9.6
Male tasters	..	2.5	16.2	45.0	32.5	3.8
Female	..	2.9	18.8	42.0	23.2	13.0
Smokers	..	3.4	20.7	36.2	31.0	8.6
Non-smokers	..	2.2	15.4	48.4	26.4	7.7
All tasters	..	2.7	17.4	43.6	28.0	8.1

Two comments are appropriate. In the first place it is observed that there is a tendency for tasters to favour the first sample of a pair presented to them. In a tasting test where real comparisons are to be made, randomisation of the order of tasting within a pair would obviate any bias due to this tendency. In the second place it is seen that the percentage of non-smokers who detect differences of a low order is much higher than the corresponding percentage of smokers who detect such differences. By expectation, in a 'uniformity trial' a high proportion, ideally 100 per cent., of the differences should fall in the -3 to $+3$ class. Therefore any group of tasters, in this case the non-smokers, whose pair difference distribution shows the greatest approximation to the theoretical distribution may be considered to be the most efficient group.

In arranging a second uniformity trial, tasters who had come up to expectation in detecting differences of a low order in the first trial were asked to compare two samples one of which was known to be inferior to the other. The inferior sample contained solvent-extracted cocoa butter which carried a considerable taint of the petroleum-ether solvent. 'Good' and 'bad' samples were issued, under code, for tasting during the mornings and afternoons of four consecutive days. Of the ten tasters taking part in this panel seven were non-smokers. At the conclusion all the non-smokers and two of the three smokers were strongly in favour of the standard sample. Total pair differences ('Good'—'bad') as percentages are shown in Table 24.

TABLE 24

Pair difference	..	-9 to -3	-3 to +3	+3 to +9	+9 to +15	+15 to +20
Percentage observations	..	0.0	11.3	35.0	38.8	15.0

It was then desired to compare the flavours of four samples of chocolate, two of which (A and B) were standard samples from Britain, the second of them being the officially accepted standard of the Cocoa

Scientific Advisory Committee of the B.F.M.I.R.A., and the other two (C and D) were samples prepared at WACRI by the improved techniques outlined earlier. Sample C was the product of a routine fermentation and D was the product of an experimental fermentation. The panel comprised twenty-two members, six of whom had shown consistency in the uniformity trial and whose judgements could be analysed separately. Pairs of samples were issued for tasting on the mornings and afternoons of each of three consecutive days, the order of tasting each member of a pair, and the time and day on which that pair was to be tasted having been determined at random. The subsequent statistical analysis followed the usual lines for this type of incomplete block design.

Table 25 shows the results obtained in terms of mean score per sample.

TABLE 25
Mean Sample Scores

			<i>Sample</i>				
			<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>S.E</i>
All tasters	..	..	10.99	12.57	9.73	6.70	0.61
Six 'best' tasters		only	11.42	12.50	9.67	6.42	0.97

The panel has demonstrated a difference which was not altogether unexpected between chocolates prepared locally and those prepared in Britain but sample C does not differ significantly from sample A.

It is seen from the table that the same measure of discrimination is obtained whether the results of the six 'best' tasters are used as when an additional sixteen 'unknown' tasters are employed. Although there is an increase in the percentage standard error with the smaller number of tasters it results from the much lower level of replication rather than from a true increased variability, and it may be expected that the most efficient means of taste panel operation would be to repeat a complete series with a small panel of known high performance rather than to derive the required amount of replication by the use of additional 'unknown' members.

Bean size of Scavina (T_{12}) Cacao

Amongst the new selections submitted to manufacturers' panels in Great Britain and the U.S.A. for quality appraisals were Nanay and Scavina (T_{12}) selections; these were considered by British manufacturers to be undesirable for commercial use on account of the small bean size. In the case of Scavina, large quantities of beans were available for examination and a special study of bean size in this selection was made to detect any possible improvement in size with

increasing age of the trees. Table 26 shows the weights of the unfermented and fermented beans of Scavina, as compared with those of Amelonado from the routine pickings during the season.

TABLE 26
Bean Weight of Amelonado and Scavina cocoas

	July	Aug.	Sep.	Month of picking		Dec.	Jan.	Feb.
				Oct.	Nov.			
W.A.A.								
Wet bean size (gm.)	2.59	2.59	2.46	2.50	2.48	2.56	2.36	2.20
T.12								
Wet bean size (gm.)	2.42	2.45	2.37	2.75	2.54	2.52	2.28	2.12
W.A.A.								
Dry bean size (gm.)	1.15	1.13	1.15	1.12	1.09	1.13	1.08	1.05
T.12								
Dry bean size (gm.)	1.00	1.01	0.97	1.00	1.01	1.01	0.98	0.93

It is seen that despite an increased wet bean weight during the height of the season the dry bean weight of T12 does not equal that of Amelonado at any period of the year. The recovery rate is correspondingly lower in the Amazon cocoa. Nevertheless these beans are showing signs of reaching the prescribed minimum 1 gm. per bean as laid down by the British Chocolate Industry (Campbell, *Rep. Lond. Cocoa Conf.* 1947). This remark is contradictory to that made in the Quarterly Report of the Institute (No. 36, 1954, p. 12) where it was stated that an improvement in the bean size of this selection was not taking place. The table presented above results from a more detailed examination of the full body of data which was not available at the time of writing the interim report. There remains the possibility that the effect is purely a seasonal one though the evidence in favour of this explanation is not strong. The mean dry bean size for Amelonado cocoa for the previous three seasons is 1.10 gm. against 1.11 gm. for the season in question. It therefore seems desirable to continue these observations.

During the past crop year ten local selections and twelve introduced types have been fermented by the open mesh bag technique as replicated samples for quality appraisal. Particular note has been taken of the percentage recovery, bean size and purple bean content of these selections. So far as the local selections are concerned the results of the experiments made in 1951 have been confirmed and it appears that bean size is improving. The smallest bean of any of the local selections tested this year is 1.19 gm.; the largest bean is 2.29gm.,

and the average of all ten is 1.58 gm. Three selections, chosen by the plant breeder for their yield potential, were submitted to Messrs Cadbury Brothers Limited for flavour assessment and two of these, R15 and ACU85, were found to be within the West African Amelonado range but the third, X40, was rejected on account of a foreign flavour described as 'mouldy'. No visible trace of mould could be detected in these beans themselves nor in the 'mother' bean mass which was part of the routine Amelonado fermentation later sold as 100 per cent. pure Grade I Gold Coast Cocoa.

INSECTICIDE STUDIES

Effect of Insecticides on Fruit setting and Yield. (R. Knight)

In Volume 1 of *Cacao en Colombia*, it is reported that copper fungicides applied to cacao appreciably reduce the yield by inducing flower shedding and by inhibiting pollination (Naundorf, G., *loc. cit.*, pp. 71-82). Similar results are also said to follow treatment with DDT, Chlordane and Toxaphene (Naundorf, G. and Miller, R., *loc. cit.*, pp. 87-88). Since copper fungicides are recommended in Nigeria for the control of black pod disease and DDT in various formulations is recommended for capsid control in the Gold Coast and Nigeria, it is of importance to examine the effect of these spray materials in local conditions.

Three copper fungicides, applied at much lower concentrations than those normally used in the field, were found to inhibit pollen germination on agar plates. Newly pollinated flowers sprayed with such fungicides at ordinary field strengths failed to set and cytological examination showed that this was due to failure of the pollen tubes to grow. When flowers were sprayed at different intervals after pollination, it was found that the greater the time elapsing between pollination and spraying, the greater the amount of setting. When flower buds were sprayed prior to opening, no reduction in setting occurred.

Spraying with a proprietary DDT emulsion had similar effects but, in addition, even very dilute emulsion caused shedding of unopened flower buds.

An area of mature cacao at Tafo has been dusted with 5 per cent. DDT dust at three-weekly intervals for over three years, but no adverse effect on the gross yield is apparent. Similarly the spraying trials for control of black pod disease do not suggest that copper fungicides depress gross yields.

Systemic Insecticides. (H. R. Mapother)

There is some evidence to suggest that second and subsequent doses of Hanane applied by trunk implantation in the same bore holes as the first dose are not completely absorbed by the tree. In an

experiment involving five trees, mealybugs were successfully established on three trees four weeks after a second dose had been applied.

In the last Annual Report (p. 30) reference was made to the appearance of pathological symptoms in cacao trees which had been treated with Hanane by trunk implantation. The experiment was continued until the fifty experimental trees had received seven doses of Hanane at intervals of eight weeks. Leaf scorch and withering were evident on some of the trees early in the course of treatment; this, in many cases, was followed by severe die-back of the lower branches, later extending into the canopy and was accompanied by copious production of chupons. Some trees, however, developed no unusual symptoms and all the trees recovered when the treatment was discontinued.

Trials of the insecticidal effect of trunk implantation with Hanane, conducted in collaboration with the team of Pest Control Ltd, were discussed in the last Annual Report. The work was continued to examine the amount of radial spread of the insecticide from the bore holes and the persistence of the insecticide in the tree.

In the first trial 378 trees and dosage rates of 75, 150, 225 and 300 p.p.m. on the estimated weight of the tree were used. To investigate radial spread of the insecticide, two spacings of holes, at 2 in. and 4 in. between centres, were employed. Six weeks after treatment the trees were felled and mealybugs on them were counted. This trial was conducted in April and May 1953.

In the second trial 308 trees and dosage rates of 75, 150, 225, 300 and 375 p.p.m. on estimated tree weight were used. As a result of information obtained in the first trial, holes were drilled only at the 4 in. spacing. Mealybug counts were made on half the trees six weeks after treatment and on the other half after nine weeks. This trial took place between October and December 1953. Statistical analysis has shown that increasing the number of holes did not increase the efficacy of Hanane at any dosage level employed. Further, it has shown that in both trials the number of mealybugs present after treatment is inversely proportional to the quantity of Hanane used. The additional benefit, however, resulting from doubling a dose of 150 p.p.m. was considerably less than that of doubling a dose of 75 p.p.m. The smallest populations remained when doses between 280 and 320 p.p.m. were used. The first trial showed that a population equivalent to one mealybug on every three trees may occur following an application of 281 p.p.m. of Hanane. The second trial gave the figure of nine mealybugs on every ten trees to be expected after a dose of 317 p.p.m. It should be stressed that all mealybug populations are subject to great variation and there is a chance of one in twenty that some trees may have populations higher than four

mealybugs per tree in the first trial or seven mealybugs per tree in the second trial.

Consideration has been given to combining the results of the two trials which took place under differing rainfall conditions. By taking from the experiment such parts as are common to both and by adjusting the populations of the first experiment to allow for the natural changes taking place, it can be shown that a dose of 261 p.p.m. w/w is most likely to be effective over the range of climatic conditions examined. The population expected to follow this dosage is equivalent to eight mealybugs on five trees with a chance of one in twenty that some trees will have populations higher than four mealybugs per tree. It is worthy of note that when counting populations six and nine weeks after treatment the numbers of mealybugs greatly increased during the additional three weeks. The proportionate increase in population was twice as great in treated as in untreated trees.

ARBORICIDES

(H. R. Mapother)

The Commission of Enquiry into the Swollen Shoot Disease of Cacao in the Gold Coast, reporting in 1948, recommended that research on the chemical destruction of trees associated with swollen shoot should be given a very high priority (Report, par. 31). Work on this problem was accordingly started in 1950 and an account of the inception of the work and the techniques employed is given in the Annual Report for 1950-51 (pp. 44 *et seq.*). The destruction of diseased cacao trees by means of chemicals is of little practical importance since 'cutting out' is at least as economical as poisoning and is much more rapid. The giant alternative host trees of swollen shoot disease, however, are in a different category and their destruction on a large scale is only practicable by the use of poisons. The work with arboricides has consequently been devoted principally to the destruction of large forest trees, with especial reference to *Ceiba pentandra* and *Cola cordifolia* which commonly grow to enormous proportions, are difficult and expensive to fell, are alternative hosts of cacao virus and are undesirable shade trees for cacao on other grounds.

The materials used in these trials are all known to be efficient herbicides and many of them had already been used with success as tree poisons in various parts of the world. They comprised the following twelve preparations:

- (i) Sodium arsenite in aqueous solution containing the equivalent of 35 and 50 per cent. As_2O_3 .
- (ii) Sodium arsenite solutions made up with gelatinised starch to contain the equivalent of 5, 10 and 20 per cent. As_2O_3 .

- (iii) 'Weedicide'—a solution containing sodium arsenite equivalent to 35 per cent. As_2O_3 .
- (iv) Ammonium sulphamate as dry salt ('Ammate').
- (v) High Aromatic Oil—a distillate containing 60 per cent. of aromatic compounds.
- (vi) 'Atlacide'—a product containing 60 per cent. sodium chlorate and a fire suppressant.
- (vii) 'Santophen 20'—an emulsion concentrate containing 20 per cent. pentachlorophenol; this was diluted for use with technical white oil to mixtures containing 5 and 10 per cent. of concentrate.
- (viii) n-butyl esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and mixtures with technical white oil.
- (ix) Corresponding iso-propyl esters and mixtures in white oil.
- (x) YF 2619—an emulsion containing 25 per cent. each of the n-butyl esters of 2,4-D and 2,4,5-T, diluted for use to 5 per cent. concentrate in white oil.
- (xi) YF 2631—a similar preparation to the preceding, but containing 35 per cent. of the n-butyl ester of 2,4-D and 17 per cent. of the ester of 2,4,5-T.
- (xii) YF 2717—an emulsion concentrate containing 33 per cent. butyl ester of 2,4,5-T.

All the preparations caused the death of *Ceiba* trees to which they were applied. Some *Cola* trees survived treatment with Weedicide, Ammate, Atlacide, pentachlorophenol and esters of 2,4-D. The esters of 2, 4, 5-T appear to be more efficient tree poisons than do those of 2, 4-D.

It is thus evident that these alternative hosts of swollen shoot disease can be killed without difficulty, not only by the use of arsenic but also by materials of low mammalian toxicity. The trees have taken from one to three years to die, but this is not necessarily a disadvantage. As a rule the poisoned trees disintegrate slowly and comparatively little damage is caused to the cacao growing beneath them; on the average such damage is of the order of ten cacao trees per forest tree.

CHERELLE WILT

(A. D. McKelvie)

As a result of the study of the development of several hundred hand-pollinated pods of Amelonado, Trinitario and Amazon types of cacao it has been found that cherelle wilt occurs in two distinct waves. The first period of wilt or 'first wilt' begins a few days after the time of fertilization and lasts for nine to ten weeks, with a peak at about seven to eight weeks. The second period of wilt or 'second wilt' lasts from

nine to ten weeks till fourteen weeks with a peak at about twelve weeks. After fourteen weeks, corresponding to a pod of 13-14 cm. long there is no more wilting. The pods used in these experiments were hand-pollinated on six different dates from February to June so that allowance could be made for seasonal effects on wilting.

The weekly figures for percentage wilt were calculated on the basis of the number of healthy pods at the beginning of the week. Second wilt very rarely occurs in young cacao trees, where first wilt can account for up to 95 per cent. of all pods set. Second wilt is most abundant in August-September amongst main crop pods, on mature trees.

The peak during first wilt coincides with the formation of cell walls in the endosperm. Second wilt occurs as embryo growth becomes rapid and ceases as pod metabolism increases, coupled with starch and fat formation.

No physical differences have been observed between healthy and wilted pods during first wilt. Embryo abortion is being studied but no conclusion can as yet be drawn. Pods wilting in second wilt have abnormally well developed embryos and very thin pod stalks.

Spray applications of 50 p.p.m. 2,4-dichlorophenoxyacetic acid and naphthalene-acetic acid to young pods have been ineffective in preventing wilt.

Prevention of flushing in young clonal material (by removal of developing leaf buds) produced a reduction in wilt for a few weeks. More pods were formed on the trees where flushing was prevented than on control trees but percentage wilt was very constant. The treated trees matured their crop much earlier in the season than the control trees. Yield differences between the treatments were not significant. The experiment is being repeated on a larger scale.

Growth substance assays were carried out on extracts from ovules of healthy and wilted pods. While it has not been possible to identify any substances, differences have been observed between healthy pods and pods just beginning to wilt. There are also differences in the growth substances of healthy pods of different size.

Chromatograms were run of alcoholic extracts of ovules to detect amino-acids. The free amino-acids of healthy and wilted ovules differ in that tryptophan is almost entirely lacking in the latter. This is of interest since tryptophan is an intermediate in the formation of indole-acetic acid, a plant hormone.

The facts obtained from this study reveal a strong resemblance between fruit drop of deciduous fruit crops and cherelle wilt of cacao. With this in mind a series of field experiments is being laid down to test methods of controlling pod setting and wilting in an attempt to increase yield.

THE ROLE OF 'SHADE' IN CACAO CULTIVATION (J. F. Archibald and S. N. Adams)

Introduction

Cacao is usually grown under shade, but no scientific explanation of the practice has been given. The role of shade is clearly complex and the following factors may be of importance:

- (1) Reduction of insolation.
- (2) Soil protection by canopy and leaf litter.
- (3) Nutrition by leaf-litter mulching, and removal of nutrients by root competition of shade species.
- (4) Soil moisture: its maintenance by canopy and removal by root competition.
- (5) Preservation of atmospheric humidity by windbreak effect and by reduction of temperature under the canopy.

A thorough understanding of the relative importance of these various effects is essential to enable shade management to be conducted by scientific as opposed to rule-of-thumb methods. Furthermore, in the light of such knowledge, it should be possible to decide under what conditions, if any, shade is unnecessary.

The purpose of these investigations is to distinguish these different functions of shade and to assess their relative importance.

Shade Conditions and Fertilizer response

A NPK trial on Amazon seedlings grown in pots was conducted in full sunlight and in artificial shade provided by a plant barn. All plants were grown in shade until the first flush had hardened and the 100 per cent. light plants were then put into the open. This transfer was later seen to have been a mistake; for two weeks afterwards the 100 per cent. light plants made little growth and showed leaf scorch. Once acclimatised to the new conditions, though, there was no difference in the growth rates (as measured by leaf areas) between the 100 per cent. light and the shade plants, and no more leaf scorch was seen. All plants were harvested seventy-eight days after the transfer into light. No difference in response to fertilizers was observed between the shaded and unshaded plants.

A more detailed trial has been started using replicated and more precisely defined shade. To avoid the leaf-scorch of the preliminary experiment, all plants are being grown from the start in the light conditions which they will have to experience throughout their growth.

The effect of forest litter on the growth of young seedlings

A field experiment has been started to investigate the effect of forest litter removal on the growth of Amelonado seedlings. Inorganic and organic mulch treatments are included to see if any adverse effects of litter removal can be offset by other means.

Effect of organic and inorganic mulches in relation to shade and fertilizer treatment

An experiment was laid down in the clonal nursery to test a number of factors included in the term 'shade'; this area was employed because the only existing shade was tree cassava and *Gliricidia*, thus avoiding the complication of large forest tree species. Three types of shade treatment were used:

- (i) No shade.
- (ii) Shade provided by cut palm fronds to reduce effect of insolation without the competition provided by living shade.
- (iii) Sparse, living top-shade of tree cassava and *Gliricidia*.

One hundred and eighty seeds of Amelonado type cacao were sown singly at a spacing of 4 ft. by 4 ft. in each treatment.

Each shade treatment block was divided into six plots, each of thirty plants, to which the following treatments were given:

- (i) Sulphate of ammonia applied at 5 gm. per plant when the first flush had hardened (this application was to attempt to offset any Nitrogen deficiency resulting from the use of organic mulch).
- (ii) Sulphate of ammonia plus organic mulch.
- (iii) Sulphate of ammonia plus an inorganic mulch (sand) to give soil protection without the possible nutrient effect of an organic mulch.
- (iv) Organic mulch, no added Nitrogen.
- (v) Inorganic mulch, no added Nitrogen.
- (vi) No added Nitrogen, no mulch. The plants in this treatment were ring weeded.

Observations on height, leaf number and leaf product are made at two-monthly intervals from the time of hardening of the first flush. One gallon of water per plant is given fortnightly during the dry season.

At the hardening of the first flush the plants without shade had suffered from leaf-eating insects to a greater extent than those from the other shade treatments. This largely accounted for the slight depression in leaf products in this treatment which was the only difference observed between the treatments.

Effect of 'day-length' and fertilizer treatment on growth of cacao seedlings

The preliminary experiment was started to test the effect of submitting cacao seedlings to varying periods of full insolation, rather than attempting to reduce the incident light by a known amount compared with full exposure.

Frames covered with aluminium sheeting were constructed to exclude a large proportion of the available light. Temperature within

the frames was lower than external air temperature during the day and higher at night, with a range of about 8°C. All treatments were covered with frames at night to avoid night temperature differences between the four light treatments. 'Day-length' is used conveniently to describe the treatments, although there is no absolute distinction between light and dark, but a very large reduction in the light intensity under the shades compared with full exposure. Four 'day-length' treatments were applied:

- (i) 4 hr.; 08.00—12.00 hr.
- (ii) 4 hr.; 12.00—16.00 hr.
- (iii) 8 hr.; 08.00—16.00 hr.
- (iv) 12 hr.; 06.00—18.00 hr.

Twenty-four pots were allocated to each treatment with two single-cotyledon seeds to each pot. The position of the pots within each light treatment was changed daily to help obviate the effect of uneven lighting under the frames. The tops of the pots are covered with 'kraft' paper, and the pots shaded laterally to reduce soil temperature effects.

Four fertiliser treatments were applied during the proliferation of the first flush:

- (i) N—Sulphate of ammonia—2 gm. per pot.
- (ii) P—Superphosphate—8 gm. per pot.
- (iii) K—Potassium sulphate—0.5 gm. per pot.
- (iv) O.

Observations of height, leaf number and leaf product are made monthly from the hardening of the first flush. In addition weekly leaf counts are made. Leaf-eating insects caused considerable damage and the plants were sprayed with lead arsenate, causing some scorch damage, especially to the plants receiving four-hour exposure. Results to the time of hardening of the second flush show that prolonged full exposure had resulted in short plants with a greater number of small hard-textured leaves, compared with the four-hour exposures. The leaves in full exposure have been dark green and small throughout, whilst the plants in the four-hour treatments had large, thin and very pale green leaves. There was some evidence of increased growth rate in terms of leaf area in those plants receiving phosphate, being particularly marked in those receiving full exposure.

Ibadan Sub-Station

VIRUS RESEARCH

(R. M. Lister and J. M. Thresh)

Host Range

Attention has been chiefly devoted to the search for natural infections, particularly in *Cola chlamydantha* and *Adansonia digitata*. It

is hoped to make collections and tests of the former in the Cameroons during the coming months, and a number of specimens of *Adansonia digitata* have already been tested. Trees with virus-like symptoms have been found in the Northern Region near Funtua, which is in the Sudan Savannah vegetation zone, but no positive back-tests have been obtained from them so far. The help of the Departments of Agriculture is being sought in finding suspect *Adansonia* trees for testing, and record sheets similar to those in use in the Gold Coast have been prepared and circulated.

Classification of Cacao Viruses

The Offa Igbo observation plot is one of the plots marked out and mapped by the Cocoa Survey Division in July-August 1953 for their own experimental work. Since that time it has also been used by the Substation as an observation plot. A check has been made of the efficiency of three methods of detecting infection—the normal examination for symptoms made by the Cocoa Survey, examination by Substation staff and back-tests from each tree by means of grafts. Records of the number of trees flushing were started in June 1954, when it appeared that the number of new infections detected might be related to this.

Of the test plants, most of which were successfully grafted by January 1954, a number have produced interesting and apparently anomalous results. Grafts taken in December 1953 from four symptomless trees produced symptoms on the test seedlings although the trees themselves have failed to show symptoms in twelve subsequent monthly observations. The four trees are being retested by further transmission tests. A fifth tree showed symptoms in the eleventh month after graft material, which infected test seedlings, had been taken from it. These observations indicate the possibility of a very long incubation period for the virus in some trees. Successful grafts made in December 1953 from fourteen trees bearing symptoms have so far produced no symptoms in the test seedlings. This might indicate that the virus is not fully systemic in the infected trees, and this is being examined further.

Yield recording on an individual tree basis was started in August 1954 at the Offa Igbo plot and also at the Koroboto observation plot of 900 trees.

As a preliminary to protection work on the Nigerian cacao viruses, nine isolates collected from various parts of the infected areas have been transmitted to seedlings, and the symptom patterns produced are being recorded. It is clear from these observations that some isolates of Nigerian swollen shoot virus can have severe effects on the growth of seedlings. One isolate from Asijere seems to have greater

effects than the virulent New Juaben strain of the Gold Coast, since in a few months it can produce defoliation and death of some plants infected in the bean stage whereas the New Juaben strain does not usually kill seedlings.

TABLE 27

The effect of nine Nigerian isolates on the growth of seedlings infected in the bean stage

Isolate	Leaf Measurements cm. ² *						S.E. of the mean	Significantly different from healthy growth at P =
	Plant I	Plant II	Plant III	Plant IV	Plant V	Mean		
Asijere ..	30	36†	135	207	121	106	30	.001
Aladie ..	337	104	101†	146	—	172	48	.001
Iwo ..	286	250	328	287	408	311	26	.001
Ife ..	310	332	299	347	391	336	14	.001
Olanla ..	316	404	297	289	350	331	20	.001
Offa Igbo ..	436	326	471	489	486	441	29	.01
Ijaye ..	495	417	484	426	588	482	31	.01
Ilesha ..	736	548	398	665	350	540	66	.05
Elepo ..	677	633	1,047	425	637	684	91	—
Healthy ..	690	1,049	943	716	626	805	75	—

* These values are the sum of the products of leaf length and breadth for all leaves on each plant and are proportional to the total leaf area.
 † Plant died.

Leaf measurements of the seedlings were recorded after three months to estimate the effect of the nine isolates on growth. Table 27 gives the results of an analysis of the leaf measurements of the plants in the first experiment of the series, and it is clear that eight of the isolates have a significant effect on growth as compared with healthy seedlings. In an experiment on the incubation period of the Offa Igbo isolate, single twigs on fifteen selected trees were infested over a period of ten days with several hundred mealybugs bred on infected source plants. Material from various parts of the canopy of the trees was tested for infection by grafts and insects, and the time taken for the development of infectivity was compared with that required for symptoms to appear.

In some trees infectivity was not detected before symptoms developed, but others became infective before symptoms appeared. Leaf symptoms developed in one tree forty-seven days after first infestation, and in six other trees after sixty-five days. The first symptoms produced in some trees were on branches which had not been infested, and on other trees symptoms were first seen on basal chupons. These observations indicate that there is rapid virus movement throughout

the tree. A technique has been developed for measuring the rate of movement of virus in seedlings infected by mealybugs, and this may provide evidence as to whether the virus travels in the translocatory tissues.

Mechanical Transmission

It has been confirmed that water extracts of cacao leaves decrease the infectivity of tobacco mosaic virus as measured by the production of local lesions on leaves of *Nicotiana glutinosa*.

In the course of this work a strain of tobacco mosaic virus producing a systemic mosaic disease in a number of leguminous plants was isolated from cowpeas growing on Moor Plantation. This appears to be the first record of a tobacco mosaic virus producing a systemic disease in any legume, and the observations have been written up for publication.

Coppicing as an adjunct to cutting out

Until recently the policy in the area of intensive survey in Nigeria has been to cut out infected trees together with all apparently healthy trees within thirty yards of visible infections. Table 28 summarises the available information on the Cocoa Survey treatments and re-treatments and it will be seen that large numbers of apparently healthy trees are destroyed particularly in treating small outbreaks.

TABLE 28
*Treatment and Retreatment of Outbreaks in
Nigeria, May 1950—October 1954*

<i>No. of trees in outbreak</i>	<i>No. of outbreaks treated</i>	<i>No. of infected trees cut out</i>	<i>No. of apparently healthy trees cut out</i>	<i>Ratio apparently healthy to infected</i>
1-4	22	41	3,694	90
5-12	16	143	6,549	46
13-28	18	343	10,634	31
29-60	24	1,030	25,141	24
>61	27	11,142	127,279	11
Total	107	12,699	173,297	14

(Data from Cocoa Survey Division Headquarters, Ibadan)

To obtain information on the pattern of spread and on the extent of unrecognised infection, a series of coppicing experiments was started in March 1954. Many outbreaks have now been coppiced by the Substation in association with the Cocoa Survey Division and Table 29 summarises results of observations on the first six.

TABLE 29
Results of Experiments in Nigeria on coppicing

Locality	Total number of trees coppiced	Observed before felling	Number of infections	
			Additional revealed on felling	Additional revealed on regeneration
Egbu	832	8	*	19
Abudoro	1,132	12	*	—
Agunmu	39	13	*	6
INA farm	274	20	4	7
Alagbe	764	70	11	6
Adifa	998	25	14	9†

* Inspection of felled trees not carried out in these experiments.

† Symptom observation not yet complete.

Observations made on three of these areas show that inspection of standing trees from ground level does not reveal all the symptom-bearing trees in an outbreak and it has now been definitely established that symptom-bearing chupons may be produced from the stumps of trees which were symptomless when meticulously examined before and after felling.

In general, the new infections revealed by coppicing were either in contact with or near to trees found to have symptoms at the time of coppicing. Some of the infections revealed were more distant, and in one case symptoms were found on the chupons of stumps on the edge of the treated area, thirty-three yards from the nearest infected tree. Coppicing has revealed infection in only a small proportion of symptomless trees. This observation has stimulated the present interest in coppicing in association with cutting out as a routine treatment of virus outbreaks. Coppicing reveals the extent of virus infection with greater precision, reduces the rehabilitation problem, and provides a method of avoiding a great deal of the wastage of healthy trees.

At present the Cocoa Survey Division are cutting out infected trees and coppicing apparently healthy ones around many outbreaks. The information being collected will give further information on the spread of virus and may enable present methods to be modified.

To determine the most satisfactory techniques for coppicing trees and maintaining the subsequent growth, a series of experiments has been started by the Substation at the Ibadan Native Administration Farm (I.N.A.).

(i) *Virus Outbreak Area.* Twenty infected trees and a surrounding area of healthy ones were coppiced at three different heights during the rainy season. Observations have been made on the initiation of chupons and the appearance of swellings.

Symptoms have been found on the chupons developing from all the regenerating stumps of infected trees, with the exception of the

chupons from the stump of one tree which was originally classified as doubtfully infected by Cocoa Survey. There is considerable variation in the amount of growth from different infected stumps, and graft and insect transmissions have been carried out to see if this variation is related to genetic differences in the host, or to variation in virulence of virus between the trees of the outbreak.

All the chupons from infected stumps continued to grow throughout the dry season following coppicing and no infected stumps died during this period. These observations differ considerably from the records made in the Gold Coast (*Ann. Rep. WACRI*, 1945-46) on the regeneration from stumps infected with the New Juaben virus and they suggest that the I.N.A. virus has less severe effects on growth. Leaf symptoms are not usually seen on material infected with the I.N.A. virus and stem swellings are the characteristic symptom.

(ii) Chupon number and chupon pruning experiment. The 1,350 trees on two acres of the Old Spacing Trial have been coppiced and regeneration is being compared allowing 1, 2, 3, or 4 chupons to develop from the cut stumps. The Belgian Congo pruning technique is being applied to half of each plot.

(iii) Shading and mulching experiment. This is a $2 \times 2 \times 2$ factorial experiment on the 600 trees of two one-acre plots which were coppiced at the beginning of the dry season.

The treatments are:

- (a) Palm leaf shade *v* none.
- (b) Cocoyams around the stump *v* none.
- (c) A mulch of banana stems around the stump *v* none.

Oil palm shade and banana mulch are often applied as a routine treatment to seedlings during the dry season and it was thought that cocoyam might provide a useful temporary shade for the young chupons in the dry season. By the end of the dry season none of these treatments had produced any marked effect on the growth of chupons. It therefore seems unlikely that shading or mulching cut stumps will have a major beneficial effect on the early growth of chupons when trees are coppiced at any time of year.

(iv) Effect of Season on regeneration. Differences have been found in the rapidity with which coppiced stumps produce chupons when cutting has been carried out at different times of the year. Fewer chupons develop and they take longer to appear when trees are coppiced during the relatively cool, wet-season months of June, July and August as compared with coppicing during the warmer months.

It appears that temperature effects are important and it is interesting to observe that during the cloudy periods at the height of the rains, maximum daily temperatures are usually below 83°F, a temperature given by Humphries (*Ann. Bot. N.S.* **8**, 1944, p. 260) as being critical for the bursting of cacao buds.

In order to obtain more precise information on the effect of climatic and edaphic factors on regeneration, at least fifty selected trees are being coppiced each fortnight from two acres of mature cacao. Routine temperature, humidity and rainfall records are maintained at I.N.A. and each fortnight samples of soil are taken from various depths for moisture determination. Immediately before coppicing, records are made of the girth, condition and flushing status of each tree.

(v) Coppicing Height and Earthing up Experiment. Two hundred and thirty cacao trees have been coppiced during the dry season, with a slightly sloping cut, from 3 in., 6 in., 9 in., or 12 in. Half the trees in each group have been earthed up and the advisability of painting the cut surface of the stump is also being investigated. So far it appears that there is no relation between regeneration and coppicing height. This result differs from that obtained on the virus outbreak area during the rains, where more failures were recorded when the trees were cut at 6 in., as compared with those cut at a higher level.

(vi) Regeneration in Relation to the Size and Condition of the Tree. On all experiments tree girth has been recorded at the time of coppicing and a scoring system has been worked out for recording the general condition of each tree. The assessment is a subjective and visual one, but reproducible results have been obtained between observers. The classes of the assessment are as follows:

Class 1: Complete canopy. Damage to the tree visible only on close inspection.

Class 2: Damage to the tree obvious but not extensive.

Class 3: Damage to the tree obvious. Sections of the canopy showing die-back, dead leaves, or a leafless condition, but damage not so extensive as to promote chupon development along the main stem.

Class 4: Canopy largely or totally destroyed. Chupon development along the main stem, in extreme cases the tree alive at the base only.

The results from several coppicing experiments treated in October or November 1954 have been summarised in Table 30. It will be seen that regeneration has been very successful and that losses only became appreciable on coppicing the most severely damaged trees. This result may also be important in relation to the regeneration of capsid pockets.

TABLE 30

Condition of tree before coppicing and its effect on regeneration

<i>Canopy Class</i>	<i>No. of trees</i>	<i>Stumps not regenerating</i>	<i>Stumps failing after regeneration</i>	<i>Total failed</i>	<i>Survival (%)</i>
1	185	5	3	8	96.0
2	514	6	4	10	98.0
3	555	33	9	42	92.0
4	412	89	29	118	71.5
Total	1,666	133	45	178	Mean=89.0

In later work class 4 has been sub-divided and preliminary results indicate that losses are largely confined to trees which are alive at the base only. Losses are not restricted to any particular size of tree (Table 31) and are confined to stumps which entirely fail to develop chupons and others which die after making unsatisfactory growth.

TABLE 31

Girth of trees and its effect on regeneration

<i>Girth Class</i>	<i>Total No. of trees</i>	<i>Stumps not regenerating</i>	<i>Stumps failing after regeneration</i>	<i>Total failed</i>	<i>Survival (%)</i>
1"-4"	80	3	5	8	90.0
5"-8"	186	19	14	33	82.2
9"-12"	202	24	4	28	86.1
13"-16"	317	44	10	54	82.9
17"-20"	602	34	11	45	92.5
21"-24"	234	6	1	7	97.0
>25"	45	3	—	3	93.3
Total	1,666	133	45	178	Mean=89.0

There was no evidence of a difference in the ability of the trees in different girth classes to produce chupons. Although there is evidence that smaller trees may produce chupons more rapidly than larger ones the subsequent rate of growth of chupons is greater on larger stumps and this is likely to be related to size of root system.

(vii) Mineral Deficiency Symptoms. Trees have now been coppiced in many of the cacao-producing areas of the Western Region and in many localities leaves on new chupon growth have been found showing a chlorotic condition. This was at first thought to be due to over-exposure, but the symptoms resemble those described for iron deficiency by Greenwood (*Emp. J. Exp. Agric.* **19**, p. 73, 1951) and Maskell, Evans and Murray (A Report on Cacao Research, I.C.T.A., 1945-51; *ibid.*, 1953) and a greening response has been obtained with a 1 per cent. ferrous sulphate solution sprayed on chlorotic leaves. In most

cases the deficiency symptoms are mild and are not associated with any great effect on growth, but some examples have been found of severe stunting with yellowish-white leaves and necrosis similar to that illustrated by Murray (A Report on Cacao Research, I.C.T.A., 1952, 1953). Symptoms of iron deficiency have also been found on mature trees and it appears that acute or chronic iron deficiency, or non-availability, is common in the Western Region.

In addition to iron deficiency symptoms, leaf distortion and mosaic typical of zinc deficiency have also been noted in many areas where coppicing has been carried out, and in some cases growth appears to have been adversely affected.

MEALYBUG STUDIES (R. G. Donald)

Biological Control of Mealybugs

Nineteen species of primary parasites, three of hyperparasites and three rare species the status of which is not known, have been reared from cacao mealybugs in Nigeria. Of the primary parasites three species of *Anagyrus* and one each of *Blepyrus*, *Pseudaphycus*, *Metaphycus* and *Leptomastix* have not so far been recorded from the Gold Coast, and are not very common in Nigeria. *Leptomastix bifasciatus* Comp. is by far the most abundant, having been reared from all the commoner mealybug species, and accounting for over 25 per cent. of all primary parasites. *Neodiscodes martinii* Comp. is next in numerical importance (over 15 per cent.) but is rarely reared from hosts other than *Planococcus citri* Risso, *P. kenya* (Le P.) and *Pseudococcus njalensis* Laing.

About 90 per cent. of the hyperparasites reared have been *Cheiloneurus carinatus* Comp. the others being *Achrysopophagus aegyptiacus* Mercet and an unknown species, probably a *Coccidoctonus* sp., which also attacks the larvae of predacious Cecidomyiidae, on which it is a primary parasite.

The most abundant predators are larvae of Cecidomyiidae, of which at least two species occur. While they are mainly predacious on nymphal mealybugs, they may complete their life cycle as ectoparasites on a single adult host in which case egg production by the host is often reduced or inhibited entirely, depending on the stage of development of the host at the time of attack. Cecidomyiids are attacked by two parasites namely the probable *Coccidoctonus* sp. mentioned above, and *Calliceras* sp.

Ten species of Coccinellidae attack cacao mealybugs, the commonest being *Platynaspis higginsii* Crotch and *Scymnus* (*Pullus*) sp. *P. higginsii* is found mainly in ant-attended colonies of *P. njalensis*, *P. kenya* and less frequently, *P. citri*, while the *Scymnus* sp. most commonly attacks unattended colonies of *P. citri*, or those attended by *Pheidole* spp. Two

species of *Hyperaspis* and at least six other *Scymnus* spp. also occur. *Brumus foudrasi* Muls. attacks *Antonina graminis* Mask. on grasses, and *Phenacoccus madeiriensis* Green on a number of host plants, but has not been collected in association with cacao.

The commonest parasite of Coccinellidae is *Homalotylus africanus* Tim., which attacks *Scymnus* spp., and is in turn parasitised by *Thysanus* sp. and an unidentified Encyrtid. A further *Homalotylus* sp. and two unidentified species have also been reared.

Larvae of the Lycaenidae *Spalgis lemolea* Druce and *Aslauga vininga* Hew. prey on all stages of mealybugs, the former on *Ferrisiana virgata* (Ckll.), *P. madeiriensis* and *P. citri* and the latter on *P. njalensis*. Larvae of a third species of Lycaenidae have been found in colonies of *P. njalensis* attended by Crematogasterine ants, but have not been proven to be predators.

Over 700 parasites and predators have been sent to taxonomists for identification. A full report on the survey of cacao mealybug parasites in Nigeria is being prepared for publication elsewhere when these insects have been identified.

The relative abundance and distribution of different species of mealybugs

Investigations into the relative abundance and distribution of the various species of mealybugs attacking cacao in Nigeria have been conducted concurrently with the survey of their natural enemies reported on above. During the year, until the survey ended in January 1955, all mealybug colonies on the trunks and all branches within reach from ground level were collected from 146 batches of ten trees. The trees within the batches were selected at random within single farms or plots of cacao, and batches were taken from various localities and at different dates. Each mealybug colony was collected separately, together with ant attendants when present, and notes were taken on the position of the colony and on the presence or absence of protective 'ant tents'. The adults and nymphs in each colony were later counted, using a low power microscope, and representatives from each were mounted on slides for identification.

One thousand and two colonies were collected from 424 of the trees, the remaining 1,036 trees having no mealybugs on the parts examined. One hundred and ten colonies contained only unidentifiable nymphs and in a further twenty-nine the adults were so damaged by parasites or predators that identification was impossible.

Eighty-two mixed colonies were found, mainly of two species each, though four of them contained three distinct species of mealybug. *Planococcus citri* was the most frequently encountered species, 313 colonies being of this species alone while it also occurred in forty-four of the mixed colonies. Colonies of *Pseudococcus njalensis* and *Planococcus*

kenyae were each about half as common as those of *P. citri* (153 and 151 pure colonies and in 31 and 18 mixed colonies respectively).

Other species encountered were *Ferrisiana virgata*, *Pseudococcus buko-bensis* Laing, *Pseudococcus concavocerarii* James, *Pseudococcus* sp. nr. *proteae* Hall, *Pseudococcus* sp. nr. *gahani* Green, *Dysmicoccus brevipes* (Ckll.), *Helicococcus* sp., and a species belonging to an unknown genus. The data obtained do not lend themselves to simple statistical treatment, and expert advice has been sought on the matter. However no seasonal variation has been obvious during the course of this work except in the case of *F. virgata* and *P. concavocerarii* which are most frequently found attacking flowers or very young cherelles and are therefore more commonly collected when these are abundant. Variations in the composition of the mealybug population within certain plots have been noted from time to time, but do not appear to be due to seasonal effects since comparable changes do not necessarily occur at the same time in plots only a few miles apart. No differences in the distribution of the various mealybug species have been observed between different cacao-growing areas of Nigeria that could not be due to the variations noted in the previous sentence.

To determine whether sampling from the ground gave a true picture of the mealybug fauna of branches twenty-four cacao trees at I.N.A. Farm were felled and examined in detail after they had been sampled from the ground in the usual way. Two hundred and seventy-one colonies containing 885 mealybugs were thus obtained, the total population per tree ranging from 0 to 165.

TABLE 32
Relative Abundance of Mealybug Species

<i>Species</i>		<i>From ground level</i>	<i>Site Remainder of Tree</i>	<i>Whole tree</i>
<i>Pl. citri</i>	..	47.0	21.7	26.5
<i>P. njalensis</i>	..	4.2	31.8	26.5
<i>Pl. kenyae</i>	..	5.4	19.4	16.6
<i>F. virgata</i>	..	32.7	2.9	8.6
<i>P. sp. nr. proteae</i>	..	1.8	3.2	2.9
<i>Ps. concavocerarii</i>	..	1.2	1.8	1.7
<i>Ps. buko-bensis</i>	..	0	2.0	1.6
Various (3 spp.)	..	0	0.4	0.3
Unidentifiable	..	7.7	17.0	15.2
		100.0	100.0	99.9

The following observations are of interest:

- (a) Only 19 per cent. of the total mealybug population on these trees was collected before felling (figures for individual trees ranged from 0 to 87.5 per cent.).

- (b) Most species could be found in collections from ground level as well as in collections from the canopy of felled trees (Table 32).
- (c) The average number of individuals per colony varied from one species to another, e.g., *P. njalensis*, 7.2; *P. citri*, 3.3; *P. sp. nr. proteae*, 1.7.
- (d) The average number of individuals per colony for all species together was higher (4.3) in collections made from ground level than on the rest of the tree (3.1) despite the predominance of *P. njalensis* in the canopy.
- (e) *P. njalensis* colonies were most frequently found in capsid cankers and similar wounds, while *F. virgata* and *P. concavocerarii* appeared to favour flowers, very young cherelles, and growing buds.

APPENDIX

RESEARCH PROGRAMME 1955-56

1. VIRUS RESEARCH

- (a) Elucidation of the host range of the swollen shoot viruses and virus strains of cacao in the Gold Coast and Nigeria.
- (b) Recognition of the optimum conditions for transmission of swollen shoot virus by mealybugs and their relation to virus spread in the field.
- (c) Classification of the viruses and virus strains affecting cacao in West Africa.
- (d) Techniques for mechanical transmission of swollen shoot virus: involving the removal of tannins, mucilage and other ingredients from host extracts; purification of virus extract; effect of various ingredients of cacao extracts on the infectivity of other viruses.
- (e) Effect of host plant nutrition on susceptibility to infection, on symptom expression and on rate of virus multiplication. The studies will be extended to field experiments according to the results obtained.
- (f) Chemical detection of virus infection.
- (g) Morbid histology of virus-infected cocoa.
- (h) Examination of resistance and tolerance in selections exhibiting these characters, especially in Iquitos selections and their seedling progeny.
- (i) Coppicing as an adjunct to cutting out for swollen shoot disease; related problems.

2. MEALYBUG STUDIES

- (a) Movement of mealybugs in and between standing trees.
 - (b) Effect of wind currents on mealybug dispersal. It has already been shown that mealybugs are often carried by the wind: the practical importance of this type of dispersal is to be examined, together with the conditions in which it occurs.
 - (c) Study of the seasonal variation in mealybug populations in different types of habitat, including study of the factors leading to the development of exceptionally large mealybug populations.
 - (d) Observations on winged ants to determine to what extent mealybugs are carried on mating flights.
 - (e) Chemistry of mealybug secretions.
 - (f) Methods for mass-breeding mealybugs.
- (See also para. 11, Insecticide and Fungicide Studies.)

3. STUDIES OF BLACK POD DISEASE

- (a) Spraying trials for the control of black pod disease. Two major experiments will be continued; the spraying trial will compare the effect of Perenox, Blitox, Carbide-Bordeaux, Bordeaux Mixture and no treatment and the effect of frequent harvesting.
- (b) Investigation of the methods of spore dispersal; study of air dispersal and soil infection; dry season phase of the fungus.
- (c) Study of cushion infection and its relative importance in the production of diseased pods.
- (d) Assessment of losses in Gold Coast and Nigeria.

4. CAPSID STUDIES

- (a) Further investigation of the regeneration of areas seriously damaged by capsids by coppicing, with especial reference to the protection of new growth by residual insecticides.
- (b) Trial of a 'squirting' method for the protection of young bearing trees with DDT and Lindane.
- (c) Comparative trial of dusts and wet mists for capsid control on fully mature trees.
- (d) Trials for the control of capsids by treatment of pods only with a variety of residual insecticides at critical seasons.
- (e) Cultural control. Effect on yield and capsid damage of stoppage of vertical growth at the first jorquette, with removal of chupons and local insecticide treatment.
- (f) Capsid bionomics, including the effect of climatic and local environmental factors on capsid abundance, and the quantitative study of capsid eggs.
- (g) Investigation of fungi associated with capsid lesions.
- (h) Assessment of losses due to capsid attack.

5. EXPERIMENTS ON ESTABLISHMENT AND MAINTENANCE

(a) Establishment Trials.

- (i) First establishment trial. Continuation of this rather complex experiment, which compares different types of planting material and methods of planting (see Annual Report 1948-49, p. 57).
- (ii) Second establishment trial. Comparison of the following treatments: (α) selective underbrushing, temporary shade of tree cassava, final shade of forest trees; (β) planted in bush traverses, final shade to be tree cassava, cacao pruned to one tier of fan branches; (γ) planted in bush traverses, no supplementary shade, final shade to be forest trees.

- (iii) Third establishment trial. To investigate the use of local food crops (cassava, maize, cocoyams and plantains) as temporary shade and their effect on establishment and yield.
- (iv) Optimum age for planting rooted cuttings in the field.
- (v) Comparison of effects of planting cuttings in bush traverses with planting in underbrushed land with temporary shade.
- (vi) Observations on irrigation as a factor in the establishment of cuttings.
- (b) Spacing trials. Effect of different spacings on the establishment, growth and yield of Amelonado and Upper Amazon cacaos.
- (c) Shade trials and observations. Trials of methods for the renewal of forest canopy in mature cacao; re-afforestation as a preliminary to cacao re-establishment.
- (d) Comparative yield trials of seedlings and rooted cuttings. Selected types of Amelonado, Upper Amazon and Trinitario cacaos will be established as rooted cuttings and as seedlings at varying spacings and their yield and general performance will be observed.
- (e) Effect of soil type on pod development and yield: correlation with soil analyses.
- (f) Methods of forecasting yields of cacao. The amount of pod setting which occurs at critical times of the year is recorded on a series of sample plots and a relation is sought between this and the final yield of the areas represented by the sample plots.
- (g) Study of the effect of retention and removal of chupons on rooted fan cuttings.

6. SOIL FERTILITY AND MANURIAL REQUIREMENTS

- (a) Field experiments to determine the effect of various amounts and combinations of major nutrients on (i) the growth and development of newly established Amelonado cacao; (ii) growth and development of young, bearing Upper Amazon cacao; (iii) yield of fully bearing Amelonado cacao.
- (b) Comparison of the effects of different sources of the major nutrients on the growth and yield of newly established and mature Amelonado and Upper Amazon cacao.
- (c) Examination of the effect of nitrogen and phosphate on newly-planted farmers' cacao.
- (d) Analysis of profile samples from sites of all the preceding experiments, to be related to the responses obtained.
- (e) Examination of the physical and chemical characters of good and bad cacao soils.

- (f) Investigation of the means and degree of uptake of major nutrients by analysis of plant organs and by observations of growth rate.
- (g) Investigation of factors limiting growth in the early life of cacao seedlings. Observations on the effect of mulching, watering and manuring with nitrogen and phosphate in an attempt to accelerate the growth of seedlings in the first year.
- (h) Role of minor elements in cacao nutrition.

7. VEGETATIVE PROPAGATION

Improvement of vegetative propagation methods to facilitate the production of rooted cuttings of 'difficult' types and species.

8. PLANT BREEDING AND SELECTION

- (a) Progeny and Introductions Trials. Analysis of yield, vigour, bean size, quality and habit of local selections and introduced types of cacao occurring in the experimental areas of the station. Observations will also include studies of susceptibility to attack by pests and diseases and the material studied will include trees reported by the Department of Agriculture as of outstanding performance.
- (b) Continuation of the breeding programme. The best trees indicated by the observations under (a) above are to be employed as parents for breeding work, having regard to (i) preserving Amelonado quality, (ii) securing high early yield, (iii) securing large bean size and low shell percentage, (iv) producing trees with compact habit of growth.
- (c) Comparative growth and yield trials of Amelonado, Trinitario and Upper Amazon types selected under (a) on different soil types and in different climatic zones.
- (d) Comparative study of *Herrania* and *Theobroma* species. Especial attention will be paid to (i) resistance to black pod disease, (ii) resistance to cacao viruses, (iii) fat and alkaloid content.
- (e) Study of inter-specific crosses. The production, characters and possible economic value of crosses between *T. cacao* and other *Theobroma* and *Herrania* species.
- (f) Mechanics of pollination. Investigation of the maximum distance over which cross-pollination occurs; this leads to the determination of the optimum spacing of pollen-supplying trees in plots of self-incompatible cacao. Plots of EI and of albino cacao will be used as test plants.

- (g) Study of incompatibility in cacao. The genetics of incompatibility within Upper Amazon types will be further elucidated. Investigations will be undertaken on the incompatibility systems in Trinitario types, Ecuador selections and in incompatible Gold Coast selections. The cytology and physiological causes of incompatibility will be studied.
- (h) Study of the genetics and morphology of hereditary characters of cacao. This involves recognition and detailed study of important characters of the cacao plant. The ultimate aim is to produce chromosome maps as an aid to scientific breeding and its accomplishment will involve work extending over some twenty years.
- (i) Production and study of polyploidy with a view to the production of fertile inter-specific hybrids.
- (j) Investigation of the possibility of prolonged storage of pollen without loss of viability.
- (k) Establishment in nucleus plots of types believed to be promising parents and likely to be used in the production of new selections.

9. CACAO FERMENTATION AND QUALITY

- (a) Investigation of the chemical changes occurring during the fermentation of cacao beans. This is performed mainly by small-scale fermentation experiments and assessment of the quality of the products. The work has especial reference to the changes affecting the polyphenols in the beans, which are believed to be associated with flavour and aroma, and to the various external factors, e.g., pulp sugars, which affect fermentation. Amelonado and Upper Amazon types are considered separately.
- (b) Investigation of the changes in 'purple' bean content of cured cocoa during storage.
- (c) A survey of fermentation methods employed by cacao farmers.
- (d) A study of methods for the evaluation of cocoa quality by taste panels.
- (e) Study of the factors affecting variation in content of cocoa fat and alkaloids in cured cocoa (especially seasonal and climatic factors).

10. PIN-HOLE BORER INVESTIGATIONS

Study of the factors predisposing to borer attack; insect species involved; economic role of the insects; methods of control.

11. INSECTICIDE AND FUNGICIDE STUDIES

- (a) Effect of insecticides and fungicides on fruit setting and yield.
- (b) 'Screening' trials with new systemic and other insecticides, followed by field trials where appropriate.

12. PHYSIOLOGY OF NUTRITION, GROWTH AND FRUITING

- (a) Qualitative and quantitative studies of the distribution of roots of healthy and diseased cacao growing on contrasted soil types. Study of the relation of the distribution of cacao roots to those of shade trees and of possible natural root-grafting. Rate of growth of cacao roots.
- (b) Study of absorption of mineral nutrients.
- (c) Investigation of the distribution of growth substances associated with early growth.
- (d) Investigation of the function of the tap root.
- (e) Investigation of cherelle wilt.

13. STUDY OF THE EFFECTS OF 'SHADE' IN CACAO CULTIVATION

- (a) Fertiliser treatment effects in relation to shade conditions.
- (b) Effect of forest litter on growth of young seedlings.
- (c) Effect of organic and inorganic mulches in relation to shade and fertiliser treatments.
- (d) Comparison of yields of shaded and unshaded mature cacao.
- (e) Effect of soil cover on water economy of cacao seedlings.
- (f) Effect of day length and fertiliser treatment on growth of cacao seedlings.
- (g) Distribution of rainfall and soil moisture under shaded and unshaded cacao.

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